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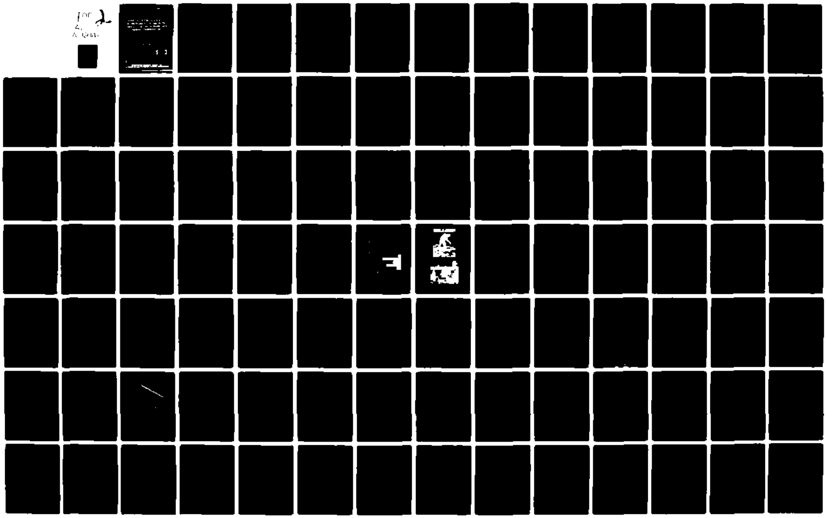

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EFFECTS OF FUEL VOLATILITY ON DRIVEABILITY OF 1980 MODEL CARS AT LOW AND INTERMEDIATE AMBIENT TEMPERATURE

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EFFECTS OF FUEL VOLATILITY ON DRIVEABILITY OF 1980 MODEL CARS AT LOW AND INTERMEDIATE AMBIENT TEMPERATURE

(CRC PROJECT No. CM-118-80)

Prepared by the

1980 Analysis Panel

of the

CRC-Volatility Group

March 1982

Light-Duty Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

Coordinating Research Council, Inc.

TABLE OF CONTENTS

TABLES *(Continued)*

Page

FIGURES

APPENDICES

Page

I. OBJECTIVE

In previous CRC studies, equations were developed to predict vehicle driveability at intermediate ambient temperatures (nominally 40-70°F) as a function of gasoline distillation properties. Such equations are useful for predicting the driveability performance of commercial gasolines. The purposes of the present study were: 1) to supplement those previous studies at intermediate temperatures with data for 1980 model year vehicles with and without closed-loop fuel control systems; and 2) to determine the relationship between fuel volatility and vehicle driveability at low ambient temperatures (<20°F), thus expanding the applicability of equations for predicting driveability performance.

II. SUMMARY AND CONCLUSIONS

Cold start and warmup driveability was measured at low (-20 to 28°F) and intermediate (40 to 69°F) ambient temperatures using 1980 model cars (10 with closed-loop and 6 with open-loop fuel systems). Nine gasolines which varied independently in distillation temperatures at 10, 50, and 90% evaporated (T_{10}, T_{50}, and T_{90}) were used. Results are described in terms of total weighted demerits (TWD), which were adjusted to reduce the influence of variations among raters. Averages were computed across cars and/or across fuels, as appropriate.

- Average TWD (132) at low ambient temperatures were not significantly different from average TWD (125) at intermediate ambient temperatures. This apparently resulted from the fact that for some cars and fuels, TWD increased as temperature decreased, and for other cars and fuels, TWD decreased as temperature decreased.

- At low temperatures, average TWD with the lowest volatility fuel (Fuel 1) were about double those with the intermediate volatility fuel (Fuel 2), while average TWD with the highest volatility fuel (Fuel 3) were about 30% lower than those with Fuel 2. At intermediate temperatures, effects were similar, but of smaller magnitude.

- At intermediate ambient temperatures, the effect of T_{10}, T_{50}, and T_{90} on driveability was similar to that found in previous CRC intermediate temperature studies. At low ambient temperatures,

however, the importance of T_{10} increased and the importance of T_{90} decreased relative to that at intermediate temperatures. The equation developed to predict driveability as a function of T_{10}, T_{50}, T_{90}, and Ta (ambient temperature in the range of -20 to 69°F) is given below:

$$\begin{aligned} TWD^{*} = & -371.7 + 0.0251 \cdot Ta + (2.0582 - 0.027171 \cdot Ta) \cdot T_{10} \\ & + (0.9925 + 0.002245 \cdot Ta) \cdot T_{50} \\ & + (0.1576 + 0.007379 \cdot Ta) \cdot T_{90} \end{aligned}$$

The following table, which has been derived from the above equation, illustrates the effect of ambient temperature on the relative importance of T_{10}, T_{50}, and T_{90}.

<u>Normalized Regression Coefficients</u>

Ta, °F	T_{10}	T_{50}	T_{90}
-20	0.73	0.27	0.00
0	0.64	0.31	0.05
20	0.53	0.36	0.11
40	0.39	0.43	0.18
60	0.20	0.52	0.28

The normalized regression coefficients at 40 and 60°F were similar to those previously obtained in a study with 1973 model cars at 40-70°F.

- With the above 8-coefficient equation, the differences between actual and predicted TWD were greatest with the fuels which had distillation curves roughly parallel to those of commercial gasolines. For example, the equation underestimates average TWD with Fuel 1 by about 15 and overestimates average TWD with Fuel 2 by about 20. To improve prediction of TWD, two nonlinear terms ($T_{10} \cdot T_{50}$ and T_{50}^2) were added to the model:

$$\begin{aligned} TWD^{*} = & 1894.6 + 0.8759 \cdot Ta - (0.0363 + 0.027829 \cdot Ta) \cdot T_{10} \\ & + (-19.5514 + 0.002388 \cdot Ta + 0.010321 \cdot T_{10}) \cdot T_{50} \\ & + 0.044768 \cdot T_{50}^2 + (0.2949 + 0.007320 \cdot Ta) \cdot T_{90} \end{aligned}$$

With this 10-coefficient equation, TWD for Fuel 1 were underestimated by only 7 and for Fuel 2 were underestimated by only 3. Because of the nonlinear terms in this equation, it was not possible to derive normalized regression coefficients such as those shown above for the 8-coefficient equation.

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*Notes regarding both regression equations: not all coefficients were significant at the 90% confidence level; indices of determination (r^2) were low due to large car-to-car differences.

- As in past programs, there were large differences among cars in driveability level and the effects of fuel volatility on driveability. However, there were no significant differences between matched open-loop and closed-loop models. The similarity in driveability between open-loop and closed-loop models apparently results from the fact that closed-loop systems are not operative during warmup.

- TWD levels for these 1980 model cars were greater than those of 1977 model cars, less than those of 1973 model cars, and similar to those of 1975 model cars which have been tested by CRC. The effect of fuel volatility on driveability of these 1980 model cars was similar to that of the 1973 models.

- Classification of demerits by malfunction and test cycle showed that hesitation, stumble, and stalls during accelerations accounted for about 80% of TWD and that most TWD occur during the first 3 cycles of the 6-cycle CRC procedure.

- Of several alternative demerit counting systems which were evaluated, only one (demerits weighted according to a scale developed in a study of customer response to driveability) gave noticeably different regression coefficients than those shown above. Further evaluation of this scale in future programs may be warranted.

III. INTRODUCTION

Based on a CRC study[1] with 1973 model year cars at intermediate ambient temperatures (40-70°F), the following equation was developed to predict cold start and warmup driveability as a function of gasoline distillation properties:

$$TWD = -285.7 + 0.6166 \cdot T_{10} + 0.8527 \cdot T_{50} + 0.4706 \cdot T_{90} \quad (1)$$

where T_{10}, T_{50}, and T_{90} are the temperatures (°F) at 10, 50, and 90 percent evaporated, respectively. This equation indicates that TWD increase (driveability deteriorates) as T_{10}, T_{50}, and T_{90} increase, and that the effect of T_{50} is greater than that of either T_{10} or T_{90}. In commercial use, the above equation is often approximated by the following relationship:

$$TWD \quad \alpha \quad 0.5 \cdot T_{10} + T_{50} + 0.5 \cdot T_{90} \quad (2)$$

A similar CRC program was conducted with 1975 model cars[2], but compatibility problems between some of the fuels and fuel systems

prevented the establishment of a new equation. Instead, the data for the fuels giving no compatibility problems were analyzed using the equation for 1973 cars. The equation developed for 1973 cars appeared to also be suitable for 1975 cars.

These preceding relationships have been useful for the prediction of the driveability performance of gasolines at intermediate ambient temperatures. However, for temperatures below 40°F, no published data were available to establish such an equation, and it could not be assumed that the equation developed for intermediate temperatures would be applicable to low temperatures. Consequently, this study was conducted to determine the influence of gasoline volatility on vehicle driveability at low ambient temperatures (-20 to 28°F).

For this study, 1980 model year cars were chosen because the 1980 models sold in California were equipped with closed-loop fuel control systems, while those sold in other states generally had open-loop fuel control systems. Thus, differences between closed-loop and open-loop cars, in driveability level and the effect of gasoline volatility on driveability, could be evaluated.

There also were several reasons for conducting driveability tests at intermediate temperatures in conjunction with those at low temperature: 1) to determine how driveability of 1980 model cars (with and without closed-loop systems) compared to that of previous model year cars studied at intermediate ambient temperatures; 2) to determine if the effect of fuel volatility on driveability was different for 1980 than for previous model years; and 3) to allow direct comparison between low and intermediate temperatures, of driveability level and the effect of fuel volatility on driveability for the same cars operated at the same test location. This report describes the program which was conducted to meet these goals, and the results which were obtained.

IV. EXPERIMENTAL CONDITIONS AND DATA ANALYSIS TECHNIQUES

A cold-start and warmup driveability program was conducted in Brainerd, Minnesota in two phases: one at low temperature and one at intermediate temperature. The low temperature (nominally <20°F) tests were conducted from January 24 through February 24, 1980 and the intermediate temperature (nominally 40-60°F) tests were conducted from April 15 through May 14, 1980. In each test phase, trained raters evaluated the driveability of sixteen 1980 model cars using nine fuels, each with different volatility. Appendix A lists participants in the test program and program planning and data analysis panel members. The program proposal approved by the CRC Volatility Group is shown in Appendix B.

A. TEST SITE

Brainerd International Raceway was rented by CRC and used as the test site for the program. A schematic of the test site is shown in Figure 1. The facilities used by CRC included a fuel storage shed, equipment storage room, office space, overnight parking for the test cars, and the track. The driveability tests were conducted only on the front section of the track but cars were preconditioned for the next day's testing by driving them two laps around the entire three-mile track.

This location was chosen because: (1) weather records indicated that ambient temperature would be suitable and precipitation would be minimal, and (2) a suitable test site was available. As will be discussed in the next section, the weather was not as favorable as had been expected.

B. AMBIENT CONDITIONS

The distribution of ambient temperatures during each of the test runs is shown in Figure 2. The program proposal listed 0-20°F as target temperatures for the low temperature phase. However, at the time that tests were to start, ambient temperatures rarely exceeded 0°F, so the minimum test temperature was lowered to -20°F. Near the end of the low temperature phase, temperatures were often higher than 20°F. There were three days in which testing was cancelled due to high ambient temperature, and three additional days in which a portion of the tests were run at ambient temperatures above 20°F (up to 28°F).

In addition, the condition of the track was not ideal at the beginning of the low temperature phase. Shortly before the program began, several inches of snow fell in the Brainerd area. The snow partially melted then refroze, leaving an ice coating on the test track. The contractor hired for snow removal was unable to clear the ice, so critical areas were cleared manually, as is shown in Figure 3. Efforts to clear the track were only partially successful, but to minimize delays, testing was begun before the track was cleared. Several days throughout the program, testing had to be delayed a few hours until new snow could be cleared from the track.

Ambient conditions were more favorable during the intermediate temperature phase of the program. Tests were never cancelled due to rain or due to undesired ambient temperatures. There were, however, a total of 29 runs at ambient temperatures above the target of 60°F. The maximum temperature at which tests were run was 69°F.

C. CARS

Table 1 describes the 16 test cars used in this study. Eight of the cars were General Motors products, 5 were from Ford Motor Co., and 3 from Chrysler Corporation. This distribution roughly approximates the relative U.S. market share of these 3 manufacturers. A variety of model and engine sizes were selected. It was planned to test only vehicles with automatic transmissions; however, for one of the selected models, the only available car was one with a manual transmission.

Ten of the cars had closed-loop fuel systems* and 6 had open-loop systems. In general the closed-loop cars were certified to meet California exhaust emissions standards and the open-loop cars were certified to meet 49-state exhaust emissions standards. One closed-loop vehicle was certified to meet emissions standards in all 50 states Six of the closed-loop cars were matched by model and engine to the 6 n-loop cars.

Throughout the report the cars will be designated by the number through 16. Table 2 identifies each of the car numbers according fuel system type and the CRC identifying code.

The cars were leased and delivered to Brainerd several days prior to the start of the program to provide time for preparation by a local dealership. Car preparation by the dealer included:

- a check of spark timing, fluid levels, tire pressure, and emission control systems
- installation of an auxiliary fuel line mounted to the front bumper
- installation of a basket for securing a test fuel can to the front bumper (the basket is shown in Figure 4)

Prior to the start of testing, CRC participants operated the cars on the test track to establish the intake manifold vacuums to be used for the light throttle and detent accelerations (see Appendix B).

Between the low and intermediate test phases, the cars were stored in buildings at the track site.

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*Computer-controlled fuel metering based on a signal from an oxygen sensor in the exhaust system.

D. FUELS

The design set of nine test gasolines used in this program was similar to the test gasolines used in past CRC programs of this type[1,2]. They varied independently in the distillation temperatures at which 10, 50, and 90% of the sample had evaporated. A detailed description of the fuels is given in Table 3, and a graphic representation of the fuel design is shown in Figure 5. The approximate temperature range of each fuel design variable was:

Design Variable	Temperature Range, °F
10% Evap. Temperature (T_{10})	100 - 140
50% Evap. Temperature (T_{50})	185 - 245
90% Evap. Temperature (T_{90})	295 - 360

The volatility ranges were selected to approximate the range for commercial gasolines.

All test fuel for the program was blended before the low temperature phase, but only half of the total quantity of each fuel was shipped to Brainerd for the low temperature phase. The remaining fuel was stored by the blender until the beginning of the second test phase. The fuels were shipped and stored on site in 30-gallon drums. Fuel was dispensed from the drums into 2-gallon "safety" cans. The cans were installed on the front bumper of the vehicle as shown in Figure 4. Fuel was supplied to the engine via an auxiliary fuel line from the safety can to the car's fuel pump inlet.

E. TEST DESIGN

The actual test design, which is shown in Table 4, differed somewhat from that which was planned (see Appendix B). There were 8 raters (A, B, C, D, E, G, H, I) instead of 6 as in the original design. Three raters participated in only the low temperature test phase, four participated in only the intermediate temperature phase, and one rater participated in both test phases. For the purposes of rater assignment, each of the two test phases was divided into two test blocks of roughly two weeks each. There were two raters on site at the same time; both rated 8 cars each day.

F. DRIVEABILITY PROCEDURE AND RATING SYSTEM

In both phases, raters evaluated car driveability using the test procedures described in Appendix B. The driving procedure consisted of

a cold start followed by a specific series of acceleration, cruise, deceleration and idle maneuvers. The raters evaluated driveability problems such as hesitiation, stumble, surge, and idle roughness using a subjective scale of "none, trace, moderate, or heavy." Starting times were measured and the number of stalls were recorded. Based on the malfunctions observed, demerits were assigned, weighted, and totaled as described in Appendix B to provide total weighted demerits (TWD). As driveability deteriorates TWD increase. Examples of weighted demerit assignments are: 32 for an acceleration stall, 16 for a moderate hesitation, and 1 for trace idle roughness.

There were two modifications to the driveability procedure for this test program. The first involved starting. Early in the low temperature phase, there were problems with starting some cars due to insufficient battery charge. To avoid this problem during the remainder of the low temperature phase, an auxiliary battery was used to assist in cold cranking (see Figure 4). The second modification was for testing the car with the manual transmission. The driving and shifting procedures for this car are described in Table 5.

F. DATA ANALYSIS

A brief discussion of the methods used for computing means, analysis of variance, and regression analysis is given below. The technique for adjusting the data to reduce rater effects is discussed later.

1. Means

A few comments about the method used for computing means are in order. First, replicate results within each data cell defined by test phase, car, fuel, and rater block (2•16•9•2 = 576 cells) were averaged to provide a balanced data set. Means by car, fuel, and test phase were computed from this balanced data set. For analysis of variance and regression, the entire unbalanced data set was used.

2. Analysis of Variance

The significance of car, fuel, and test phase effects was evaluated using analysis of variance with the following model:

$$TWD = \mu + C_i + F_j + P_k + CF_{ij} + CP_{ik} + FP_{jk} + CFP_{ijk} + \varepsilon_{(ijk)l} \qquad (3)$$

where:

μ = the grand mean of TWD

C_i = the effect of the i\th car (i = 1-16)

F_j = the effect of the j\th fuel (j = 1-9)

P_k = the effect of the k\th test phase (k = low, intermediate)

CF_{ij} = the effect of the interaction between the i\th car and the j\th fuel

CP_{ik} = the effect of the interaction between the i\th car and the k\th test phase

FP_{jk} = the effect of the interaction between the j\th fuel and the k\th test phase

CFP_{ijk} = the effect of the interaction between the i\th car, the j\th fuel, and the k\th test phase

$\varepsilon_{(ijk)l}$ = random error resulting from the l\th replicate with the i\th car, j\th fuel, and k\th test phase

For this model C_i is a random variable because the individual cars were obtained at random from the population of each selected make and model. Previous driveability programs[1,2] showed that driveability varies among cars of the same make and model. Fuel and test phase were considered fixed variables in this model.

To determine the significance of all of the terms in the model, F tests were performed. Based on the above model with car as a random variable, the following were used to compute F values for each of the effects:

Effect	F Calculation
Car	MS(C)/MS(ε)
Fuel	MS(F)/MS(CF)
Test Phase	MS(P)/MS(CP)
Car by Fuel	MS(CF)/MS(ε)
Car by Test Phase	MS(CP)/MS(ε)
Fuel by Test Phase	MS(FP)/MS(CFP)
Car by Fuel by Test Phase	MS(CFP)/MS(ε)

where MS is the mean squares (sum of squares divided by degrees of freedom) for each term. Confidence levels were computed for each F value; levels greater than 90% were considered significant.

To determine the influence of open-loop versus closed-loop fuel systems on driveability, a different model was required:

$$TWD = \mu + S_i + C_{(i)j} + F_k + P_l + SF_{ik} + SP_{il} + FP_{kl} + FC_{(i)jk} + CP_{(i)jl} + SFP_{ikl} + CFP_{(i)jkl} + \varepsilon_{(ijkl)m} \quad (4)$$

where:

μ = the grand mean of TWD

S_i = the effect of the i\th fuel system (i = open loop, closed loop)

$C_{(i)j}$ = the effect of the j\th car within the group defined by the i\th fuel system

F_k = the effect of the k\th fuel

P_l = the effect of the l\th test phase

SF_{ik} = the effect of the interaction between the i\th system and the k\th fuel

SP_{il} = the effect of the interaction between the i\th system and

the l\th test phase

FP_{kl} = the effect of the interaction between the k\th fuel and the l\th test phase

$FC_{(i)jk}$ = the effect of the interaction between the k\th fuel and the j\th car within the i\th system

$CP_{(i)jl}$ = the effect of the interaction between the j\th car within the i\th system and the l\th test phase

SFP_{ikl} = the effect of the interaction between the i\th system, the k\th fuel, and the l\th test phase

$CFP_{(i)jkl}$ = the effect of the interaction between the j\th car within the i\th system, the k\th fuel, and the l\th test phase

$\varepsilon_{(ijkl)m}$ = random error resulting from the m\th replicate with the i\th system, the j\th car, the k\th fuel, and the l\th test phase

Again $C_{(i)j}$ is considered a random variable and all others are considered fixed. $C_{(i)j}$ is also a nested variable because individual cars can belong to only one of the car groups, i.e. it is either a closed-loop or an open-loop car. F values were computed as shown below:

Effect	F Calculation
System	MS(S)/MS(C)
Car	MS(C)/MS(ε)
Fuel	MS(F)/MS(FC)
Test Phase	MS(P)/MS(CP)
System by Fuel	MS(SF)/MS(FC)
System by Test Phase	MS(SP)/MS(CP)
Fuel by Test Phase	MS(FP)/MS(CFP)
Fuel by Car	MS(FC)/MS(ε)
Car by Test Phase	MS(CP)/MS(ε)
System by Fuel by Test Phase	MS(SFP)/MS(CFP)
Car by Fuel by Test Phase	MS(CFP)/MS(ε)

3. Regression Analysis

Regression analysis was used to develop equations for predicting driveability as a function of fuel properties and ambient temperature. A standard, least-squares multiple regression technique was used. The models for the analysis, which are described later, did not include terms to account for differences among cars. Thus, these car-to-car variations became part of the error term in the models, and result in relatively high coefficients of variation (standard error expressed as a percent of the mean) and relatively low indices of determination (r^2). The significance of all terms in the regression models was evaluated using t-tests.

V. RESULTS AND DISCUSSION

Detailed results of the driveability tests at low and intermediate temperature are given in Appendix Table C-1. Average TWD (raw) are summarized in Appendix Table C-2. As in past CRC programs, the first step in the data analysis was an attempt to reduce the influence of differences among raters.

A. RATER CORRECTIONS AND TEST PRECISION STATEMENTS

In previous CRC driveability programs[1,2,3,4] rater corrections were developed to reduce the data bias caused by differences among raters. In the analysis of results from this study, there were similar efforts to identify and remove these rater effects. The method used in this study was derived based on the test design and, consequently, was somewhat different from that used in previous CRC studies. A brief description of the technique is given here. Details are in Appendix D.

The form of the equation for rater correction was:

$$\text{Adjusted TWD} = \text{Raw TWD} + C \tag{5}$$

As is described in Appendix D, there were four steps in the process of determing the correction constants (C's) for each rater. The first step was to determine, by regression analysis, the average TWD difference between raters on site together. In the low temperature phase, average TWD differences were calculated for Rater A versus Rater B and for Rater C versus Rater D. In the intermediate temperature testing, differences for Rater D versus E, for Rater D versus G, and for Rater H versus Rater I were computed.

Second, within each test phase, an average difference between raters not on site together was determined. This involved finding the Rater A versus Rater D difference in the low temperature phase and finding the Rater D versus Rater H difference for the intermediate temperature phase.

While not all of these rater offsets were statistically significant, they were the best available estimate of the correct offset and therefore were all used in the calculation of rater correction factors.

The third step in developing the correction factors was to calculate the adjustment necessary to equalize the individual rater averages. Because only Rater D participated in both the low and intermediate temperature phases, it was decided that all other raters should be adjusted to make their average TWD equal to the Rater D average.

Applying these corrections to the data increased the overall average TWD by 1.3 TWD, indicating that rater D was about 1.3 TWD more severe than the average rater. Therefore, the fourth step was to subtract 1.3 TWD from all observed ratings by reducing each rater correction by 1.3 TWD. The final rater corrections are:

Rater	C
A	17.0
B	-15.7
C	-31.3
D	-1.3
E	-20.0
G	16.2
H	34.4
I	-1.2

Adjusted TWD data for each run are shown in Appendix Table C-1. Average results are summarized in Table 6.

Application of these rater corrections reduced the reproducibility standard error* from 55.5 to 51.5 TWD for the low temperature phase and from 40.9 to 35.3 TWD for the intermediate temperature phase. Test repeatability was 49.1 and 33.9 TWD in the low and intermediate temperature phases, respectively. (An explanation of these calculations is included in Appendix D).

A few additional comments on the rater correction factors are in order. The factors are based on the assumption that the severity of Rater D was the same in both phases of the program. This assumption seems valid, but it cannot be proven (nor disproven) because Rater D did not conduct any tests under identical conditions in both phases.

Because the correction for some raters was negative, the corrected TWD were sometimes negative. Even though TWD less than zero are technically impossible, they were retained and used in all remaining analyses to insure that the effects of fuel volatility on driveability were properly assessed. As will be shown later, these rater adjustments had little effect on the equations used to describe the effect of fuel volatility on driveability.

B. EFFECTS OF TEMPERATURE (TEST PHASE), FUELS, AND CARS

The results in Table 6 show differences i driveability among the cars and fuels as well as differences between low and intermediate temperature test phases. To determine whether these differences were

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* This includes the random variable components: repeatability, day-to-day variability, and rater-to-rater variability.

significant, an analysis of variance was conducted using the model described earlier. Table 7, which summarizes results of the analysis of variance, indicates that there were significant differences in driveability among the cars and fuels selected for this study, and that the interaction between car and fuel was significant. Although differences between the test phases were not significant as a main effect, there were significant interactions between car and test phase and between fuel and test phase. Discussion of each of these effects is given below.

1. Temperature (Test Phase) Effects

Average TWD (across cars and fuels) for the low temperature phase were 132.3, about 8 demerits greater than the 124.5 average for the intermediate temperature phase. Considering the large effect of temperature on fuel vaporization, a larger difference between low and intermediate temperature driveability might have been expected.

However, it is important to note that there were highly significant interactions between fuel and test phase and between car and test phase, indicating that the effect of temperature varied among the fuels and cars in this study. To more adequately understand the observed temperature effect, it is important to examine results for individual fuels and cars.

2. Fuel Effects

Figure 6 shows TWD averaged across cars for each fuel and test phase. The fuels are identified by number and by relative T_{10}, T_{50}, and T_{90} values. Results averaged across fuels for each test phase are also shown.

The expected volatility effect is illustrated by the three fuels with nominally parallel distillation curves, Fuels 1, 2, and 3. At low temperature, for example, TWD with the low volatility fuel (Fuel 1) were nearly double those with the intermediate fuel (Fuel 2), while TWD with the high volatility fuel (Fuel 3) were about 30% lower than those with Fuel 2. At intermediate temperature the same effect was apparent, but the magnitude of the differences between Fuels 1, 2, and 3 was smaller than that at low temperature.

Figure 6 indicates that the effects of temperature on driveability were different for the different fuels. For most fuels, driveability was worse (TWD were higher) at low temperature than at intermediate temperature. However, there were 3 fuels, Fuels 3, 4, and 7, for which driveability was better at low than at intermediate temperature. The only common characteristic among these three fuels is their low T_{10} values.

To illustrate the relative importance of T_{10} on low and intermediate temperature driveability, Figure 7, a plot of TWD versus T_{10}, was constructed for fuels with common values of T_{50} and T_{90}. For each test phase there are four pairs of data points representing all four possible combinations of high and low T_{50} and T_{90}. Each data pair shows increased TWD with increasing T_{10}, but the effect is noticeably more pronounced at low temperature, as indicated by the steeper slopes of the lines for low temperature in Figure 7. In a subsequent section this effect will be quantified using regression analysis.

3. Individual Car Effects

Results averaged across fuels for each car and test phase are shown in Figure 8. Nine cars had higher TWD at low temperature than at intermediate temperature, but the remaining 7 had higher TWD at intermediate temperature.

The large differences among cars in the effects of ambient temperature on driveability probably result from differences in engine calibration. Engine design factors which affect driveability include air-fuel ratio and exhaust gas recirculation (EGR). Calibrations for air-fuel ratio and EGR vary with ambient temperature; these variations could have a significant influence on the effect of temperature on driveability. Thus, the functional relationship between driveability and temperature depends on the air-fuel ratio and EGR calibration of a particular car.

The cars are grouped in Figure 8 according to fuel system (open loop and closed loop). Although there were large differences among cars in driveability level and the effect of ambient temperature on driveability, there were no apparent differences between open-loop and closed-loop cars. Effects of open-loop versus closed-loop fuel systems will be investigated in more detail in the following section.

4. Effects of Vehicle Fuel System (Open vs. Closed Loop)

Since differences among cars were so large, analysis of effects of fuel system were conducted using only the closed-loop cars for which there were matching open-loop models (see Table 2). For this set of matched cars, TWD were averaged by fuel system for each fuel and test phase, and are shown in Figure 9. At intermediate temperature, average TWD for the closed-loop cars were lower than those for the open-loop cars, but at low temperature, average TWD for the closed-loop cars were higher than those for the open-loop cars. The effect of changes in fuel volatility appeared to be similar for open-loop and closed-loop cars.

To determine the significance of the differences shown in Figure 9, analysis of variance was conducted using the model described earlier, and the results are summarized in Table 8. According to the results of

this analysis, driveability of open-loop cars was not significantly different from that of closed-loop cars and there were no significant interactions involving fuel system. This lack of significant effect of fuel system probably results from the fact that closed-loop controls are generally not operative during warmup.

5. Comparison to Previous Model Year Vehicles

To show trends in driveability level and the response of driveability to changes in fuel volatility, the results of this study with 1980 cars were compared to similar data for 1973 cars[1], 1975 cars[2], and 1977 cars[3]. For the 1980 cars, only the intermediate temperature data were used because the previous studies were all conducted at intermediate temperature.

Figure 10 shows TWD plotted versus fuel volatility (expressed in terms of $0.5 \cdot T_{10} + T_{50} + 0.5 \cdot T_{90}$) for each of the 4 studies. TWD levels for these 1980 cars were greater than those of the 1977 cars, less than those of the 1973 cars, and similar to those of the 1975 cars which were tested. The slope of the line through the data points in Figure 10 represents the effect of fuel volatility on driveability; this slope was similar for 1980 and 1973 model cars. Relationships between fuel volatility and driveability will be explored in more detail in the following section.

C. EQUATIONS FOR PREDICTING DRIVEABILITY AS A FUNCTION OF FUEL VOLATILITY

The fuels used in this study were selected so that regression analysis could be used to develop equations for predicting driveability as a function of the fuel distillation temperatures, T_{10}, T_{50}, and T_{90}. Various regressions were conducted; they are summarized in Tables 9 and 10, and will be discussed below.

1. Separate Equations for Each Test Phase

In previous CRC studies, equations for predicting gasoline driveability performance were based on intermediate temperature data only. To permit comparison between this and past programs, an equation was developed for just the intermediate temperature phase of this study:

<u>Intermediate Temperature</u>

$$TWD = -386.5 + 0.6664 \cdot T_{10} + 1.1285 \cdot T_{50} + 0.5770 \cdot T_{90} \qquad (6)$$

Equation 6 is similar, but not identical, to that obtained for 1973 model cars (equation 1). The magnitude of the slope coefficients and the absolute value of the intercept were all somewhat greater in equation 6 than in equation 1. However, the relative sizes of the slope coefficients were very similar, as is shown by the normalized forms of the equations:

Intermediate Temperature

$$\text{TWD (1973 models)} = -285.7 + 1.9399 \cdot (0.32 \cdot T_{10} + 0.44 \cdot T_{50} + 0.24 \cdot T_{90}) \tag{1a}$$

$$\text{TWD (1980 models)} = -386.5 + 2.3719 \cdot (0.28 \cdot T_{10} + 0.48 \cdot T_{50} + 0.24 \cdot T_{90}) \tag{6a}$$

These equations indicate that the relative importance of T_{10}, T_{50}, and T_{90} on driveability performance at intermediate temperature was quite similar for 1973 and 1980 model cars.

An equation was also developed for the low temperature phase of this program. The convention l and normalized forms of the equation are shown below:

Low Temperature

$$\text{TWD} = -351.3 + 1.9887 \cdot T_{10} + 0.9631 \cdot T_{50} + 0.1364 \cdot T_{90} \tag{7}$$

$$\text{TWD} = -351.1 + 3.0882 \cdot (0.64 \cdot T_{10} + 0.31 \cdot T_{50} + 0.04 \cdot T_{90}) \tag{7a}$$

Comparing equation 7a to equation 6a shows that the T_{10} coefficient is much greater at low than at intermediate temperature, indicating that the effect of T_{10} on driveability was greater at low than at intermediate temperature. Conversely, the effect of T_{90} on driveability was much smaller at low than at intermediate temperature. The effect of T_{50} on driveability was also smaller at low than at intermediate temperature.

These separate regression analyses for the low and intermediate temperature data indicate that as ambient temperature decreases, the front-end of the distillation curve becomes more important, while the tail-end of the distillation curve becomes less important. If one theorizes that, at a given ambient temperature, driveability is primarily influenced by the amount of vapor formed in the intake manifold, these results can be explained. Suppose that, at a given driving condition at intermediate temperature, about one-half of the gasoline is vaporized. Thus, differences in the volatility properties of the mid-range of the gasoline are probably most important. For the same driving condition at low temperature, less than one-half of the gasoline would be expected to vaporize. Consequently, the front-end volatility characteristics of the fuel would be more important than the mid-range characteristics. Differences in the tail-end of the fuel distillation curve would be of little importance at low temperature because, for the range of fuel volatilities tested, the amount of fuel

vaporized probably never approaches 90% during this critical driving condition.

2. Combined Equation for Both Test Phases

It is apparent that equation 6 could be used to describe the driveability performance of these cars at temperatures near 50°F, for example, and equation 7 could be used at temperatures near 0°F. For temperatures between these, such as 30°F, neither equation applies. To allow prediction of driveability performance of gasoline over a range of low and intermediate temperatures, data from both test phases were used to construct a new regression model which included ambient temperature as a variable.

Regression analysis was performed using all of the data from both test phases, and the ambient temperature during each run, Ta (°F), was included in the model as a main effect and as an interaction with T_{10}, T_{50}, and T_{90} (see Model B in Table 9). The resulting equation is shown below:

$$\begin{aligned} TWD = {} & -371.7 + 0.0251 \cdot Ta + (2.0582 - 0.027171 \cdot Ta) \cdot T_{10} \\ & + (0.9925 + 0.002245 \cdot Ta) \cdot T_{50} \\ & + (0.1576 + 0.007379 \cdot Ta) \cdot T_{90} \end{aligned} \tag{8}$$

Based on this regression equation, several observations can be made. The effect of ambient temperature on driveability was quite small and depended on fuel properties. Calculated TWD for Fuels 1, 2, and 3 at various temperatures are shown below:

	Calculated TWD (Equation 8)		
Ta, °F	Fuel 1	Fuel 2	Fuel 3
-20	204.6	132.6	65.6
0	196.4	129.9	66.2
20	188.1	127.3	66.8
40	179.9	124.6	67.3
60	171.6	121.9	67.8

Increasing ambient temperature from -20 to 60°F decreased calculated TWD by 33 with Fuel 1, decreased calculated TWD by 11 with Fuel 2, and increased calculated TWD by 2 with Fuel 3.

To demonstrate the effect of ambient temperature on the relative importance of T_{10}, T_{50}, and T_{90}, normalized regression coefficients were

computed (based on equation 8) for various temperatures; results are shown in the following table:

MODEL: $TWD = b_0 + (b_1 \cdot T_{10} + b_2 \cdot T_{50} + b_3 \cdot T_{90}) \cdot c$

Ta, °F	b_0	b_1	b_2	b_3	c
-20	-372.2	0.73	0.27	0.00	3.559
0	-371.7	0.64	0.31	0.05	3.208
20	-371.2	0.53	0.36	0.11	2.857
40	-370.7	0.39	0.43	0.18	2.506
60	-370.1	0.20	0.52	0.28	2.155

These coefficients show that driveability deteriorated with increasing T_{10}, but the effect became smaller as ambient temperature increased. Driveability also deteriorated with increasing T_{50} and T_{90}, and the effect became larger as ambient temperature increased.

Equation 8 was developed based on data obtained at ambient temperatures ranging from -20 to 69°F. This equation should not be used to predict the driveability performance of these cars outside of this temperature range. Based on this study alone, no judgment can be made on the applicability of this equation to cars other than those tested. However, the similarity of the normalized coefficients at 40 and 60°F to those developed for 1973 models at 40-70°F (equation 1a) is encouraging. Differences among cars are explored in the next section.

3. Equations for Individual Cars and Car Groups

The regression equations which have been presented above were obtained using the combined data for all cars. To determine differences in effects between cars and car groups, separate regression equations were developed for each car and for the open and closed-loop car groups. The results of these regressions are summarized in Table 10.

In general there were substantial differences in regression equations among the individual cars, but there were some similarities. Coefficients for T_{10} and T_{50} varied among the cars but were always positive. The coefficients for $T_{10} \cdot Ta$ were negative (indicating increased importance of T_{10} at low temperature) for all cars. For other terms, the coefficients were positive for some cars and negative for others.

The regression equation for open-loop cars was not significantly different from that for the matched closed-loop cars. This supports the previous analysis which showed no significant differences between open-loop and closed-loop cars in the effect of fuel volatility on driveability.

4. Equations for Fuel Volatility Expressed as Percent Evaporated

Some refiners control fuel volatility based on the percent of gasoline evaporated at a given temperature instead of the temperature for a given percent evaporated. To meet the needs of these refiners, several regressions were run with fuel volatility expressed as functions of the percent evaporated at 115, 135, 158, 215, 230, 300, and 330°F. Three such regression were run (Models C, D, and E); the results are shown in Table 9.

The regression coefficients obtained with fuel volatility expressed as a percent evaporated are of opposite sign to those with fuel volatility expressed as the distillation temperature. This was expected because increased fuel volatility results in increased percent evaporated at a given temperature, but a reduced temperature for a given percent evaporated. The r^2 and coefficient of variation for these equations were no better than those based on distillation temperature. These equations also indicate the increased importance of the front-end volatility on driveability at low temperature.

5. Equations with Higher Order Terms to Improve Prediction

It was noted during earlier discussion that the simple expression for fuel volatility (see equation 2) did not adequately predict driveability performance of all fuels. To determine the effectiveness of the overall equation presented earlier (equation 8), predicted total weighted demerits were computed for each of the nine fuels used in this study. Demerits were computed at two temperatures, 5.5 and 51.3°F (the average run temperatures for the low and intermediate test phases, respectively). These calculated TWD are compared to average actual TWD in Table 11 and Figure 11.

At low temperature there were 2 points and at intermediate temperature there were 3 points which substantially deviated from a linear least-squares line drawn through the data points. All of the points showing the relatively large deviation represent fuels with nominally parallel distillations (Fuels 1, 2, and 3). It was of some concern that the predicted demerits for these fuels did not closely correspond to the actual demerits because these fuels more closely represent commercial fuels than do the other 6.

The fuel showing the largest deviation was Fuel 2, the midpoint of the fuel design cube (Figure 1). This indicated that driveability performance was not a linear function of the distillation temperatures. Therefore, additional regression analyses were conducted with nonlinear terms involving the distillation temperatures.

A stepwise regression was run starting with the 8-coefficient model (equation 8) and adding additional nonlinear terms one at a time. The 8-coefficient equation was used as a starting point to insure that the

final equation would not contain higher order effects for which the corresponding first-order effects were missing. The regression routine was given the opportunity to select either of the squares of the distillation temperatures (T_{10}^2, T_{50}^2, T_{90}^2) or the interaction terms ($T_{10} \cdot T_{50}$, $T_{10} \cdot T_{90}$, $T_{50} \cdot T_{90}$). When the model was restricted to two additional terms (which was reasonable based on the regression results), addition of the terms, $T_{10} \cdot T_{50}$ and T_{50}^2, provided the greatest improvement in fit. The resulting 10-coefficient regression model is shown in Table 9 (Model F).

The improvement in prediction ability for the 10 coefficient model is shown in Table 11 and in Figure 12. With the 10-coefficient model, residuals (deviations between predicted and actual demerits) for Fuels 1, 2, and 3 were substantially smaller than those for Fuels 1, 2, and 3 with the 8-coefficient model. Furthermore, residuals with the 10 coefficient model for Fuels 1, 2, and 3 were similar to those for the other 6 fuels.

The utility of this expanded model would be somewhat limited however, if it applied only to these 1980 model cars. Using the data for 1973 cars[1], the following regression equation, which includes $T_{10} \cdot T_{50}$ and T_{50}^2 terms, was derived:

$$TWD = 593 + 2.99 \cdot T_{10} - 9.18 \cdot T_{50} + 0.443 \cdot T_{90} - 0.0108 \cdot T_{10} \cdot T_{50} + 0.0278 \cdot T_{50}^2 \qquad (9)$$

Figure 13 shows a plot of actual demerits versus demerits predicted according to equation 9 for 1973, 1975, and 1977 models. For each of these studies, addition of the two nonlinear terms improve the fit of the data by the equation. The improvement is particularly apparent for the fuels with parallel distillation curves.

D. CLASSIFICATION OF TOTAL WEIGHTED DEMERITS BY TEST CYCLE AND MALFUNCTION

Total weighted demerits provide an overall indication of driveability during the test, but give no information on the types of driving problems encountered, or when they occurred. In this section, demerits are compared for various portions of the test (called test cycles) and for various types of malfunctions. The rater adjustment factors developed for TWD were not applicable to demerits for each test cycle and malfunction, so no rater corrections were applied.

The demerits for individual test cycles were totaled in a manner similar to that used for TWD: within a given maneuver only the malfunctions giving the highest demerits per maneuver were counted. For the demerit classification by malfunction, however, all weighted demerits were counted. Consequently, the sum of all demerits by malfunction will generally be greater than the corresponding TWD value.

1. Demerit Accumulation by Test Cycle

To show the rate of accumulation of demerits, the test was divided into 7 parts: the initial start-up and idle period, and each of the 6 driving cycles. Demerits for Fuels 1, 2, and 3 are shown for each test part in Figure 14.

In general, the bulk of the demerits occur during the first 3 driving cycles following the start-up. During start-up and near the end of the test, the number of demerits was low. There were, however, apparent differences between the low and intermediate temperature phases in the distribution of demerits throughout the test. At low compared to intermediate temperature, for example, a proportionately larger number of demerits occurred during start-up, but a smaller number of demerits occurred during cycles 4, 5, and 6. Also, Figure 14 indicates that at lower temperature, cycle 1 demerits were substantially greater than cycle 2 demerits, while at intermediate temperature, cycle 1 and 2 demerits were roughly equal.

Differences among the 3 fuels were generally small. The relatively large percentages for Fuel 3 during cycle 1 at low temperature and for Fuel 1 during cycle 2 at intermediate temperature were apparent exceptions.

2. Demerit Classification by Malfunction

Demerits by malfunction and the total for all malfunctions, averaged across cars, are listed in Table 12. Table 13 shows the same data expressed as a percent of the total. The mean data for all fuels indicate that hesitations, stumbles, and acceleration stalls account for about 80% of the total demerits for each test phase. The percentage of demerits for acceleration stalls at low temperature (35.8%) was much greater than that at intermediate temperature (18.4%). Demerits for starting time and idle stalls were also greater at low than at intermediate temperature. The results for Fuels 1, 2, and 3 in Table 12 indicate that decreasing fuel volatility increases demerits for all malfunctions except idle roughness and surge.

E. EVALUATION OF ALTERNATIVE MEANS FOR TOTALING AND WEIGHTING DEMERITS

The CRC method for totaling and weighting demerits to obtain TWD was established during the analysis of the data for the 1972 program[1]. Although this system has been used for all CRC data obtained since 1972, various alternative systems have been proposed. To evaluate the merits of some of these alternative systems, regression equations (to predict driveability as a function of fuel volatility and ambient temperature) were developed for the following alternative demerit counting systems:

1. Normal weighting factors, but no restrictions on totaling demerits for multiple malfunctions within a maneuver.

2. Normal weighting factors and restricted totaling of demerits, but with 32 demerits assigned to each deceleration stall.

3. Weighting factors developed during a study of customer perception of driveability[4] with demerit totaling restricted to the one malfunction giving the highest demerits per maneuver.

No rater corrections were applied to these data.

The effect of these alternative demerit systems was evaluated by developing regression equations (Model B from Table 9) for each of the alternative methods. Results of these regressions are compared in Table 14 to those with the traditional demerit scale without rater adjustments. (Note that the equation for normal raw TWD counting was quite similar to the one presented earlier for adjusted TWD.) The equation obtained for demerits totaled without restrictions on multiple malfunctions within a maneuver was similar to that with the traditional demerit totaling; however, r^2 decreased and the coefficient of variation increased when the demerit totaling restrictions were removed. Inclusion of deceleration stall demerits had little effect on either the regression coefficients, r^2, or coefficient of variation.

The regression equation obtained using the customer weighting factors was somewhat different from that for the normal TWD calculations. Regressions based on the customer scale, compared to the normal scale, gave a larger r^2, but also a larger coefficient of variation. With the regression coefficients listed in Table 14 it is difficult to compare the relative importance of T_{10}, T_{50}, and T_{90} for the normal and customer demerit scales. To allow such a comparison, the average ambient temperatures for the low and intermediate temperature phases were substituted for ambient temperature in both of the models, and the results are shown in Table 15. Regression equations for both demerit weighting schemes predict that, among the 3 distillation temperatures, T_{10} has the largest influence on driveability at low temperature and T_{50} has the largest influence on driveability at intermediate temperature. The major differences between the two demerit scales occur at intermediate temperature, where the customer scale indicates increased importance of T_{10} and decreased importance of T_{50} relative to the traditional scale.

Use of the customer scale results in a regression model similar to that of the traditional scale, but the differences between the two appear sufficiently large to warrant further evaluation of the customer scale in future programs.

VI. REFERENCES

1. Coordinating Research Council, "1972 CRC Intermediate Temperature Driveability Program--Paso Robles," CRC Report No. 483, March, 1976.

2. Coordinating Research Council, "Driveability Performance of 1975 Passenger Cars at Intermediate Ambient Temperatures--Paso Robles," CRC Report No. 486, May, 1976.

3. Coordinating Research Council, "Driveability Performance of 1977 Passenger Cars at Intermediate Ambient Temperatures--Paso Robles," CRC Report No. 499, September, 1978.

4. Coordinating Research Council, "Customer Perception of Cold Start and Warmup Driveability," CRC Report No. 512, February, 1980.

TABLES

AND

FIGURES

TABLE 1. DESCRIPTION OF TEST CARS (1980 MODEL YEAR)

MAKE	MODEL	ENGINE DISP, L	CARB. BBLS.	EMISSION SYSTEM	CLOSED LOOP	AIR INJECTION	AIR COND.	VIN	MANIFOLD VACUUM* LT	MANIFOLD VACUUM* DT
BUICK	CENTURY	3.8	2	CALIFORNIA	YES	YES	YES	4H69AAH164023	11.0	2.0
CHEVROLET	CHEVETTE	1.6	2	CALIFORNIA	YES	PULSE	NO	1B689AY147578	7.0	2.0
CHEVROLET	CHEVETTE	1.6	2	49-STATE	NO	PULSE	YES	1B680AY136618	7.0	3.5
CHEVROLET	CITATION	2.5	2	CALIFORNIA	YES	NO	YES	1X685A6121364	10.5	3.5
CHEVROLET	CITATION	2.5	2	49-STATE	NO	PULSE	YES	1X085AW154471	8.0	4.5
CHEVROLET	CITATION	2.8	2	CALIFORNIA	YES	PULSE	YES	1X687A6168393	11.0	4.0
OLDSMOBILE	DELTA-88	5.7	4	CALIFORNIA	YES	NO	YES	3Y37RAX121297	11.5	3.0
OLDSMOBILE	DELTA-88	5.7	4	49-STATE	NO	YES	YES	3H69RAX112222	12.0	4.5
FORD	FAIRMONT	4.2	2	CALIFORNIA	YES	YES	YES	0K93D134123	8.5	4.5
FORD	FAIRMONT	4.2	2	49-STATE	NO	YES	YES	0K92D117640	8.0	4.5
FORD	PINTO	2.3	2	CALIFORNIA	YES	YES	NO	0T10A123994	10.0	4.5
MERCURY	BOBCAT	2.3	2	49-STATE	NO	YES	YES	0T20A605259	8.0	3.0
MERCURY	MARQUIS	5.8	2	50-STATE	YES	YES	YES	0Z64G607627	11.5	3.5
DODGE	ASPEN	3.7	1	CALIFORNIA	YES	YES	NO	NL41CAB119873	8.0	2.5
DODGE	OMNI	1.7	2	CALIFORNIA	YES	YES	NO	ZL44AAD159366	11.0	2.0
PLYMOUTH	HORIZON	1.7	2	49-STATE	NO	NO	YES	ML24AAD189995	5.0	2.0

NOTE: THE PLYMOUTH HORIZON HAD A MANUAL TRANSMISSION.
ALL OTHER CARS HAD AUTOMATIC TRANSMISSIONS.

*MANIFOLD VACUUM (IN. HG) AT WHICH LIGHT THROTTLE (LT) AND DETENT (DT) ACCELERATIONS WERE PERFORMED

TABLE 2. IDENTIFICATION OF CARS ACCORDING TO FUEL SYSTEM AND CRC CODE

CAR NO.	FUEL SYSTEM	CRC CODE
1	CLOSED LOOP	OL223]*
2	OPEN LOOP	ML223
3	CLOSED LOOP	IR457]
4	OPEN LOOP	IR457
5	CLOSED LOOP	NC5225]
6	OPEN LOOP	NC5225
7	CLOSED LOOP	NC7228
8	CLOSED LOOP	KC137
9	CLOSED LOOP	OCA242]
10	OPEN LOOP	OCA242
11	CLOSED LOOP	KI217]
12	OPEN LOOP	PI217M
13	CLOSED LOOP	NL9216]
14	OPEN LOOP	NL9216
15	CLOSED LOOP	LIA238
16	CLOSED LOOP	MWV258

*BRACKETS INDICATE MATCHED PAIRS OF CLOSED-LOOP AND OPEN-LOOP CARS.

TABLE 3. DESCRIPTION OF TEST FUELS

	FUEL NUMBER								
	1	2	3	4	5	6	7	8	9
API GRAVITY	50.6	60.1	67.1	57.3	53.5	50.2	64.5	52.3	56.6
SPECIFIC GRAVITY (60°F)	0.777	0.739	0.712	0.749	0.765	0.779	0.722	0.770	0.752
RVP, LBS.	8.9	11.2	13.6	13.1	9.5	9.5	13.1	8.8	13.4
DISTILLATION (D-86) TEMPERATURE, °F AT:									
IBP	90	84	80	80	95	92	80	91	79
10% EVAP.	134	113	99	100	126	139	98	128	105
20% EVAP.	163	135	115	122	141	175	113	146	130
30% EVAP.	191	160	135	151	156	202	131	162	162
40% EVAP.	214	189	159	192	174	223	156	179	208
50% EVAP.	237	219	187	238	193	239	193	198	245
60% EVAP.	262	242	216	267	212	254	233	226	261
70% EVAP.	295	266	234	294	229	268	270	272	273
80% EVAP.	339	301	260	321	248	283	319	318	282
90% EVAP.	362	328	308	354	296	303	356	354	294
95% EVAP.	371	342	333	368	329	321	369	366	314
EP	408	373	370	402	367	360	406	398	359
DISTILLATION, % EVAP. AT:									
115°F	5	11	20	17	8	5	21	6	14
135°F	10	20	30	25	14	9	32	14	22
158°F	18	29	40	32	31	15	41	27	29
215°F	40	48	60	45	61	36	56	57	42
230°F	48	55	68	48	71	44	60	61	45
300°F	71	80	88	72	91	89	76	76	92
330°F	78	91	95	82	95	97	83	82	98
TEMPERATURE (°F) AT 20 VAPOR-LIQUID RATIO	146	128	111	121	133	147	116	140	121

TABLE 4. TEST DESIGN

Test Design
Low Temperature Phase

Date:	1/24	1/25	1/26	1/27	1/28	1/29	1/30	1/31	2/1	2/2	2/4	2/5	2/6	2/7	2/8	2/9	2/10	2/11	2/12	2/13	2/14	2/15	2/18	2/19	2/23	2/24
Test Day:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Fuel:	6	1	7	9	2	5	8	4	3	1	2	MIXED			1	2	7	6	8	9	5	3	4	1	2	1
Car																										
1	*A	A	A	A	A	A	A	A	A	A	A	**A,6	A,8	A,5	C	C	C	C	C	C	C	C	C	C	C	C
2	B	B	B	B	B	B	B	B	B	B	B	B,1	B,3	B,4	D	D	D	D	D	D	D	D	D	D	D	D
3	A	A	A	A	A	A	A	A	A	A	A	A,8	A,6	A,7	D	D	D	D	D	D	D	D	D	C	C	C
4	B	B	B	B	B	B	B	B	B	B	B	B,1	B,8	B,7	C	C	C	C	C	C	C	C	C	C	C	C
5	A	A	A	A	A	A	A	A	A	B	B	A,6	A,7	A,9	C	C	C	C	C	C	C	C	C	D	D	D
6	B	B	B	B	B	B	B	B	B	A	A	B,1	B,6	B,9	D	D	D	D	D	D	D	D	D	C	C	C
7	A	A	A	A	A	A	A	A	A	B	B	A,3	A,3	A,7	D	D	D	D	D	D	D	D	D	C	C	C
8	B	B	B	B	B	B	B	B	B	A	A	B,1	B,9	B,6	C	C	C	C	C	C	C	C	C	D	D	C

Fuel:	7	4	2	5	6	9	1	3	5	2	1	MIXED			2	1	4	7	9	6	3	5	8	2	1	2
9	A	A	A	A	A	A	A	A	A	B	B	A,8	A,5	A,4	C	C	C	C	C	C	C	C	C	D	D	D
10	B	B	B	B	B	B	B	B	B	A	A	B,8	B,7	B,4	C	C	C	C	C	C	C	C	C	D	D	D
11	A	A	A	A	A	A	A	A	A	A	A	A,8	A,2	A,4	D	D	D	D	D	D	D	D	D	D	D	D
12	B	B	B	B	B	B	B	B	B	B	B	B,8	B,8	B,8	D	D	D	D	D	D	D	D	D	C	C	C
13	A	A	A	A	A	A	A	A	A	A	A	A,8	A,1	A,3	C	C	C	C	C	C	C	C	C	C	C	C
14	B	B	B	B	B	B	B	B	B	B	B	B,8	B,7	B,8	D	D	D	D	D	D	D	D	D	D	D	D
15	A	A	A	A	A	A	A	A	A	A	A	A,8	A,9	A,4	D	D	D	D	D	D	D	D	D	D	D	D
16	B	B	B	B	B	B	B	B	B	B	B	B,8	B,1	B,8	C	C	C	C	C	C	C	C	C	C	C	C

*Letters designate trained raters.
**Numbers designate fuels.

TABLE 4. TEST DESIGN (CONTINUED)

Test Design
Intermediate Temperature Phase

Car		4/15	4/16	4/17	4/18	4/19	4/21	4/22	4/23	4/24	4/25	4/26	4/28	4/29	4/30	5/1	5/2	5/3	5/4	5/6	5/7	5/8	5/9	5/10	5/12	5/13	5/14
	Date:	4/15	4/16	4/17	4/18	4/19	4/21	4/22	4/23	4/24	4/25	4/26	4/28	4/29	4/30	5/1	5/2	5/3	5/4	5/6	5/7	5/8	5/9	5/10	5/12	5/13	5/14
	Test Day:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	Fuel:	2	1	9	8	6	7	3	5	4	1	2	9	3	7	2	8	3	7	9	2	6	4	7	1	5	1
1		*E	E	E	E	E	E	G	G	G	G	G	G	G	G	I	I	I	I	I	H	I	I		I	I	H
2		D	D	D	D	D	D	D	D	D	D	D	D	D	D	H	H	H	H	H	I	H	H	H	H	H	I
3		D	D	D	D	D	D	D	D	D	G	G	D	D	D	I	I	I	I	I	I	I	I		I	I	I
4		E	E	E	E	E	E	G	G	G	G	G	G	G	G	H	H	H	H	H	H	H	H		H	H	H
5		E	E	E	E	E	E	G	G	G	D	D	G	G	G	I	I	I	I	I	I	I	I		I	I	I
6		D	D	D	D	D	D	D	D	D	G	G	D	D	D	H	H	H	H	H	I	H	H		H	H	I
7		D	D	D	D	D	D	D	D	D	G	G	D	D	D	I	I	I	I	I	H	I	I		I	I	H
8		E	E	E	E	E	E	G	G	G	D	D	G	G	G	H	H	H	H	H	I	H	H		H	H	I
	Fuel:	4	2	1	3	9	6	5	7	8	2	1	4	5	6	4	9	1	6	9	1	3	5	1	2	7	2
9		E	E	E	E	E	E	G	G	G	D	D	G	G	G	I	I	I	I	I	H	I	I		I	I	H
10		E	E	E	E	E	E	G	G	G	D	D	G	G	G	H	H	H	H	H	H	H	H		H	H	H
11		D	D	D	D	D	D	D	D	D	D	D	D	D	D	I	I	I	I	I	I	I	I		I	I	I
12		D	D	D	D	D	D	D	D	D	G	G	D	D	D	H	H	H	H	H	H	H	H		H	H	H
13		E	E	E	E	E	E	G	G	G	G	G	G	G	G	I	I	I	I	I	H	I	I		I	I	H
14		D	D	D	D	D	D	D	D	D	D	D	D	D	D	H	H	H	H	H	I	H	H		H	H	I
15		D	D	D	D	D	D	D	D	D	D	D	D	D	D	I	I	I	I	I	I	I	I	I	I	I	I
16		E	E	E	E	E	E	G	G	G	G	G	G	G	G	H	H	H	H	H	H	H	H		H	H	H

* Letters designate trained raters.

TABLE 5. DRIVING PROCEDURE FOR THE MANUAL TRANSMISSION VEHICLE

MANUEVER	PROCEDURE
0-25 mph light throttle acceleration	start 1st gear--shift to 2nd at 15 mph
25 mph cruise	shift to 3rd gear--cruise
25-35 mph detent acceleration	acceleration in 3rd gear
0-35 mph WOT acceleration	start 1st gear--shift to 2nd at 25 mph shift to 3rd at 35 mph
10-25 mph light throttle acceleration	2nd gear
idle	in neutral
0-45 mph crowd acceleration	start 1st gear--shift to second at 15 mph shift to 3rd at 25 mph shift to 4th at 42 mph

TABLE 6. ADJUSTED TOTAL WEIGHTED DEMERITS SUMMARY

LOW TEMPERATURE PHASE

CAR	FUEL 1	FUEL 2	FUEL 3	FUEL 4	FUEL 5	FUEL 6	FUEL 7	FUEL 8	FUEL 9	MEAN
1	215.1	124.6	85.4	166.8	141.1	148.6	110.9	156.6	132.3	142.4
2	214.0	166.5	152.2	183.7	140.5	298.5	102.5	216.5	155.0	181.1
3	255.4	66.3	25.8	121.8	108.3	142.3	62.6	116.3	191.3	121.2
4	121.0	54.3	3.0	80.0	53.5	162.0	10.0	101.3	33.0	68.7
5	112.5	32.9	26.4	50.4	41.9	100.4	26.1	79.4	50.9	57.8
6	199.9	78.7	48.0	97.0	153.0	239.7	67.5	156.0	95.5	126.2
7	419.4	298.2	231.7	297.8	293.3	313.3	255.1	329.8	241.8	297.8
8	80.6	35.2	23.5	48.0	38.0	96.5	18.5	52.5	48.0	49.5
9	286.2	174.8	133.8	174.3	246.2	321.8	132.3	197.8	292.3	217.7
10	399.4	168.3	68.0	151.3	178.2	251.5	120.7	202.0	267.5	200.8
11	174.8	91.8	77.8	76.8	96.1	145.8	56.3	100.3	119.3	104.4
12	101.7	44.6	48.5	56.0	70.7	140.0	68.0	54.0	54.5	70.9
13	254.3	179.6	134.3	165.3	131.8	211.3	146.3	153.3	194.8	174.6
14	118.5	74.2	43.0	72.0	65.2	95.0	51.7	41.5	92.5	72.6
15	354.8	148.9	80.8	178.1	235.1	352.8	87.8	250.8	313.3	228.1
16	15.8	-4.3	-10.5	-11.0	7.8	44.5	5.0	-8.5	-10.0	3.2
MEAN	207.7	108.4	73.6	119.3	128.2	191.5	82.6	137.5	142.0	132.3

INTERMEDIATE TEMPERATURE PHASE

CAR	FUEL 1	FUEL 2	FUEL 3	FUEL 4	FUEL 5	FUEL 6	FUEL 7	FUEL 8	FUEL 9	MEAN
1	221.3	94.8	63.2	137.5	60.0	134.9	85.4	126.9	132.9	117.5
2	184.4	111.1	73.8	181.5	95.0	159.0	84.8	136.0	129.3	128.3
3	205.1	61.6	41.0	164.7	30.7	158.2	53.5	88.2	88.5	99.1
4	161.0	67.7	54.8	139.3	65.8	113.7	75.7	81.2	87.2	94.1
5	117.1	44.8	40.5	77.0	58.0	53.9	33.9	51.9	63.4	60.1
6	348.0	193.3	142.3	275.5	163.5	253.5	171.8	164.5	261.5	219.3
7	346.3	221.8	193.7	319.7	242.2	340.2	229.0	234.2	242.0	263.3
8	155.2	105.5	133.3	112.3	108.8	137.2	109.2	97.2	114.0	119.2
9	230.0	131.7	53.4	145.9	85.7	182.7	99.0	162.0	151.9	138.0
10	182.9	135.4	80.2	184.2	91.0	177.2	122.3	169.3	158.7	144.6
11	140.2	79.7	64.7	136.2	69.5	97.2	103.2	95.7	107.2	99.3
12	134.9	84.7	73.5	148.5	91.8	114.3	79.5	104.5	99.0	103.4
13	208.1	109.8	110.9	178.4	64.5	207.2	131.5	151.5	207.4	152.2
14	112.9	68.9	54.0	96.8	62.8	91.3	72.5	59.5	91.0	78.9
15	211.3	110.2	33.2	136.0	101.0	132.2	104.7	138.7	108.2	119.5
16	78.0	31.2	28.2	71.2	41.3	61.7	82.8	70.3	38.2	55.9
MEAN	189.8	103.3	77.6	156.6	89.5	150.9	102.4	120.7	130.0	124.5

TABLE 7. ANALYSIS OF VARIANCE TO DETERMINE SIGNIFICANCE OF CAR, FUEL, AND TEST PHASE EFFECTS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F	CONFIDENCE LEVEL, %
CAR	15	2675883	178392	87.6	99.9
FUEL	8	1215992	151999	48.0	99.9
TEST PHASE	1	7899	7399	0.2	37
CAR BY FUEL	120	379743	3164	1.6	99.9
CAR BY TEST PHASE	15	489872	32658	16.0	99.9
FUEL BY TEST PHASE	8	92729	11591	5.3	99.9
CAR BY FUEL BY TEST PHASE	120	264170	2201	1.1	71
ERROR	530	1079480	2037		

TABLE 8. ANALYSIS OF VARIANCE TO DETERMINE SIGNIFICANCE OF FUEL SYSTEM (OPEN VS. CLOSED LOOP) EFFECTS USING DATA FOR MATCHED CARS ONLY.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F	CONFIDENCE LEVEL, %
SYSTEM	1	150	150	0.0	1
CAR	10	951864	95183	47.4	99.9
FUEL	8	955129	110391	45.7	99.9
TEST PHASE	1	8343	8343	0.4	44
SYSTEM BY FUEL	8	13211	1651	0.6	25
SYSTEM BY TEST PHASE	1	37246	37246	1.6	77
FUEL BY TEST PHASE	8	63821	7978	3.7	99.9
FUEL BY CAR	80	208977	2612	47.4	94
CAR BY TEST PHASE	10	227524	22752	11.3	99.9
SYSTEM BY FUEL BY TEST PHASE	8	13546	1693	0.8	38
CAR BY FUEL BY TEST PHASE	80	172262	2153	1.1	66
ERROR	397	798058	2010		

TABLE 9. SUMMARY OF REGRESSION ANALYSES WITH ALTERNATIVE DEMERIT SYSTEMS

MODEL	b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	COV**	r^2
INTERMEDIATE TEMPERATURE:												
A	-386.5	0.6664	1.1285	0.5770							49.3	0.22
LOW TEMPERATURE:												
A	-351.3	1.9887	0.9631	0.1364*							68.8	0.17
COMBINED:												
B	-371.7	2.0532	0.9925	0.1576*	0.0251*	-0.027171	0.002245*	0.007379			62.6	0.17
C	312.0	-5.0729	-0.1780*	-0.2592*	1.6333*	0.063541	-0.028659	-0.025779			62.8	0.16
D	348.4	-4.1290	-1.8981	-0.3535*	1.1278*	0.050078	-0.007046*	-0.023620*			62.9	0.16
E	378.8	-4.3014	-2.5518	-0.7708*	1.6352*	0.069189	-0.003410*	-0.025417*			62.8	0.16
F	1894.6	-0.0363*	-19.5514	0.2949	0.0759*	-0.027829	0.002388*	0.007320	0.010321*	0.044768	62.1	0.18

* INDICATES COEFFICIENTS NOT SIGNIFICANT AT 90% CONFIDENCE LEVEL.
** COEFFICIENT OF VARIATION (STANDARD ERROR EXPRESSED AS A PERCENT OF THE MEAN).

NOTE: THE LOW r^2 VALUES RESULT FROM LARGE CAR-TO-CAR VARIATIONS, *WHICH ARE IN THE ERROR TERMS OF THESE MODELS.*

MODEL

A $TWD = b_0 + b_1 \bullet T_{10} + b_2 \bullet T_{50} + b_3 \bullet T_{90}$

B $TWD = b_0 + b_1 \bullet T_{10} + b_2 \bullet T_{50} + b_3 \bullet T_{90} + b_4 \bullet Ta + b_5 \bullet Ta \bullet T_{10} + b_6 \bullet Ta \bullet T_{50} + b_7 \bullet Ta \bullet T_{90}$

C $TWD = b_0 + b_1 \bullet E_{158} + b_2 E_{230} + b_3 E_{300} + b_4 \bullet Ta + b_5 \bullet Ta \bullet E_{158} + b_6 \bullet TaE_{230} + b_7 \bullet TaE_{300}$

D $TWD = b_0 + b_1 \bullet E_{135} + b_2 E_{230} + b_3 E_{300} + b_4 \bullet Ta + b_5 \bullet Ta \bullet E_{135} + b_6 \bullet TaE_{230} + b_7 \bullet TaE_{300}$

E $TWD = b_0 + b_1 \bullet E_{115} + b_2 E_{215} + b_3 E_{330} + b_4 \bullet Ta + b_5 \bullet Ta \bullet E_{115} + b_6 \bullet TaE_{215} + b_7 \bullet TaE_{330}$

F $TWD = b_0 + b_1 \bullet T_{10} + b_2 \bullet T_{50} + b_3 \bullet T_{90} + b_4 \bullet Ta + b_5 \bullet Ta \bullet T_{10} + b_6 \bullet Ta \bullet T_{50} + b_7 \bullet Ta \bullet T_{90} + b_8 \bullet T_{10} \bullet T_{50} + b_9 \bullet T_{50} \bullet T_{50}$

WHERE: TWD = ADJUSTED TOTAL WEIGHTED DEMERITS
T_{10}, T_{50}, T_{90} = TEMPERATURE AT 10, 50, AND 90% EVAPORATED, °F
Ta = AMBIENT TEMPERATURE, °F
Ex = PERCENT EVAPORATED AT A TEMPERATURE OF x(°F)

TABLE 10. SUMMARY OF REGRESSION ANALYSES TO DETERMINE CAR EFFECTS

CAR	b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	COV**	r^2
1	-400.9	1.4947	0.7745	0.6271	-3.2162*	-0.013112*	0.012608*	0.004529*	25.8	0.65
2	-197.0*	1.9027	0.9906	-0.1518*	-4.2793*	-0.015356*	0.001171*	0.013896*	29.9	0.57
3	-803.5	1.6473	2.0965	0.8833	2.6253*	-0.010871*	-0.006686*	-0.002246*	50.0	0.57
4	-527.8	2.4428	0.7853	0.4399*	3.4762*	-0.037026	0.004074*	0.000871*	46.6	0.53
5	-374.5	1.3287	0.4612*	0.5579	3.0386*	-0.012638*	0.003028*	-0.006874*	58.6	0.34
6	-337.7*	4.0474	0.0256*	-0.0668*	-5.3087*	-0.067885	0.048741	0.014265*	35.0	0.63
7	-593.2	2.7949	0.5332*	1.3442	3.0850*	-0.029359*	0.017326*	-0.011971*	21.9	0.51
8	-165.1*	1.0609	0.3007*	0.0649*	4.8009*	-0.013067*	-0.001429*	-0.004491*	37.6	0.62
9	-360.7	3.0245	1.6591	-0.4012*	-4.6576*	-0.021772*	-0.004056*	0.019739	22.5	0.76
10	-1097.4	4.2956	2.2147	0.9917	14.1215	-0.068136	-0.020982*	-0.008765*	31.4	0.66
11	-337.7	1.7934	0.8139	0.1647*	1.6829*	-0.031038	-0.001029*	0.006403*	32.2	0.46
12	-173.8*	1.3122	0.6507*	-0.1775*	0.1832*	-0.023071*	-0.000509*	0.010239*	45.2	0.37
13	-344.5	0.9500*	1.0984	0.5482*	-1.8435*	-0.000908*	0.014486*	-0.005944*	27.8	0.51
14	-200.8	0.5860*	0.9857	-0.0238*	0.9479*	-0.007237*	-0.005497*	0.003529*	35.8	0.40
15	-704.1	5.5164	2.2588	-0.5892*	2.1010*	-0.071363	-0.023055	0.027920	26.3	0.81
16	-24.1*	0.7726	0.1631*	-0.3004*	-3.0166*	-0.011798*	-0.000655*	0.016703	97.7	0.48
OPEN LOOP	-408.9	2.2766	1.0934	0.0812*	0.8510*	-0.034697	0.002508*	0.008397*	56.8	0.33
CLOSED LOOP	-401.4	1.7407	1.1120	0.3062*	-1.2841*	-0.013297*	0.002417*	0.004972*	46.9	0.34
ALL CARS	-371.7	2.0582	0.9925	0.1576*	0.0251*	-0.027171	0.002245*	0.007379	62.6	0.25

MODEL: $TWD = b_0 + b_1 \cdot T_{10} + b_2 \cdot T_{50} + b_3 \cdot T_{90} + b_4 \cdot Ta + b_5 \cdot Ta \cdot T_{10} + b_6 \cdot Ta \cdot T_{50} + b_7 \cdot Ta \cdot T_{90}$

* INDICATES COEFFICIENTS NOT SIGNIFICANT AT A 90% CONFIDENCE LEVEL.
** COEFFICIENT OF VARIATION (STANDARD ERROR EXPRESSED AS A PERCENT OF THE MEAN).

TABLE 11. COMPARISON OF ACTUAL TO PREDICTED DEMERITS USING THE 8-COEFFICIENT AND 10-COEFFICIENT MODELS

LOW TEMPERATURE PHASE

FUEL	ACTUAL AVE. TWD	PREDICTED TWD 8-COEFF. MODEL	PREDICTED TWD 10-COEFF. MODEL	ACTUAL - PREDICTED 8-COEFF. MODEL	ACTUAL - PREDICTED 10-COEFF. MODEL
1	207.7	192.9	201.5	14.8	6.2
2	108.4	129.1	107.1	-20.7	1.3
3	73.6	66.1	82.2	7.5	-8.6
4	119.3	129.9	127.4	-10.6	-8.1
5	128.2	128.8	125.6	-0.6	2.6
6	191.5	190.7	197.4	0.8	-5.9
7	82.6	81.6	89.3	1.0	-6.7
8	137.5	141.1	136.7	-3.6	0.8
9	142.0	133.9	140.2	8.1	1.8

INTERMEDIATE TEMPERATURE PHASE

FUEL	ACTUAL AVE. TWD	PREDICTED TWD 8-COEFF. MODEL	PREDICTED TWD 10-COEFF. MODEL	ACTUAL - PREDICTED 8-COEFF. MODEL	ACTUAL - PREDICTED 10-COEFF. MODEL
1	189.8	174.9	182.4	14.9	7.4
2	103.3	123.2	100.7	-19.9	2.6
3	77.6	67.6	83.4	10.0	-5.8
4	156.6	147.9	145.4	8.7	11.2
5	89.5	87.6	83.1	1.9	6.4
6	150.9	146.7	152.3	4.2	-1.4
7	102.4	99.5	106.9	3.1	-4.5
8	120.8	123.8	118.2	-3.0	2.6
9	130.0	128.3	134.5	1.7	-4.5

TABLE 12. CLASSIFICATION OF DEMERITS BY MALFUNCTION

LOW TEMPERATURE PHASE

FUEL	START TIME	IDLE ROUGHNESS	IDLE STALLS	HESITATION	STUMBLE	SURGE	BACKFIRE	ACCELERATION STALLS	TOTAL
1	10.7	6.8	14.5	55.7	39.7	4.4	4.0	100.5	236.3
2	9.5	5.3	7.0	39.4	20.6	2.1	2.0	38.0	124.0
3	5.7	6.3	4.1	28.8	20.5	2.4	0.7	21.2	89.6
4	7.2	7.5	11.1	38.6	26.9	1.5	4.0	43.0	139.9
5	7.0	5.9	5.8	34.7	26.9	2.8	0.8	59.8	143.7
6	14.9	7.9	9.8	54.3	37.3	5.4	2.8	80.5	212.9
7	8.5	5.5	7.1	36.0	17.3	1.9	3.1	19.5	98.9
8	8.6	7.2	7.0	35.4	24.1	1.1	2.2	69.7	155.1
9	12.3	6.8	10.1	34.3	40.1	2.4	2.1	56.0	164.1
MEAN	9.4	6.6	8.5	39.7	28.1	2.7	2.4	54.2	151.6

INTERMEDIATE TEMPERATURE PHASE

FUEL	START TIME	IDLE ROUGHNESS	IDLE STALLS	HESITATION	STUMBLE	SURGE	BACKFIRE	ACCELERATION STALLS	TOTAL
1	2.1	14.8	4.7	67.4	55.4	5.4	6.4	63.8	220.0
2	1.1	12.7	1.3	36.5	29.7	6.8	2.5	18.0	108.5
3	0.5	14.0	0.3	23.2	29.2	4.6	1.7	4.0	77.3
4	3.4	13.8	3.9	56.1	52.1	8.1	5.9	28.5	171.7
5	0.3	13.6	0.3	31.3	27.4	6.6	1.7	12.0	93.1
6	1.0	13.8	1.6	41.7	58.5	4.4	6.0	42.5	169.5
7	2.4	14.0	2.4	28.4	38.3	5.1	3.1	9.5	103.3
8	1.8	13.2	2.8	44.6	30.8	3.5	3.9	23.0	123.6
9	2.9	13.9	2.1	47.8	45.6	5.6	1.5	20.5	139.9
MEAN	1.7	13.7	2.1	41.9	40.8	5.6	3.6	24.6	134.1

NOTE: TOTAL EXCEEDS TWD (TABLE 6) BECAUSE ALL MALFUNCTIONS ARE COUNTED.

TABLE 13. CLASSIFICATION OF DEMERITS BY MALFUNCTION, %

LOW TEMPERATURE PHASE

FUEL	START TIME	IDLE ROUGHNESS	IDLE STALLS	HESITATION	STUMBLE	SURGE	BACKFIRE	ACCELERATION STALLS	TOTAL
1	4.5	2.9	6.1	23.6	16.8	1.9	1.7	42.5	100.0
2	7.7	4.3	5.6	31.8	16.6	1.7	1.6	30.7	100.0
3	6.3	7.1	4.6	32.2	22.9	2.7	0.8	23.6	100.0
4	5.2	5.3	8.0	27.6	19.2	1.1	2.9	30.7	100.0
5	4.8	4.1	4.0	24.2	13.7	2.0	0.6	41.6	100.0
6	7.0	3.7	4.6	25.5	17.5	2.5	1.3	37.8	100.0
7	8.6	5.6	7.2	36.4	17.4	1.9	3.1	19.7	100.0
8	5.5	4.6	4.5	22.8	15.5	0.7	1.4	44.9	100.0
9	7.5	4.2	6.2	20.9	24.4	1.4	1.3	34.1	100.0
MEAN	6.2	4.3	5.6	26.2	18.6	1.8	1.6	35.8	100.0

INTERMEDIATE TEMPERATURE PHASE

FUEL	START TIME	IDLE ROUGHNESS	IDLE STALLS	HESITATION	STUMBLE	SURGE	BACKFIRE	ACCELERATION STALLS	TOTAL
1	0.9	6.7	2.1	30.7	25.2	2.5	2.9	29.0	100.0
2	1.0	11.7	1.2	33.6	27.4	6.2	2.3	16.6	100.0
3	0.7	18.1	0.3	30.0	37.7	5.9	2.2	5.2	100.0
4	2.0	8.0	2.3	32.7	30.4	4.7	3.4	16.6	100.0
5	0.3	14.6	0.3	33.6	29.4	7.1	1.8	12.9	100.0
6	0.6	8.1	1.0	24.6	34.5	2.6	3.5	25.1	100.0
[illegible]	2.3	13.6	2.3	27.5	37.1	5.0	3.0	9.2	100.0
[illegible]	1.5	10.7	2.2	36.1	24.9	2.8	3.2	18.6	100.0
9	2.1	9.9	1.5	34.2	32.6	4.0	1.1	14.7	100.0
MEAN	1.3	10.3	1.6	31.2	30.4	4.1	2.7	18.4	100.0

TABLE 14. SUMMARY OF REGRESSION ANALYSES WITH ALTERNATIVE DEMERIT SYSTEMS

	b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	COV**	r^2
NORMAL (RAW) TWD	-390.5	2.0799	1.0118	0.2142*	0.0045*	-0.027419	0.003267*	0.006412*	61.7	0.19
NORMAL WEIGHTS, W/O RESTRICTIONS	-426.2	2.1532	1.1281	0.2525*	-1.3969*	-0.024277	0.005589*	0.008155*	68.2	0.16
NORMAL TWD, COUNTING DECELERATION STALLS	-430.1	2.2444	1.0364	0.2890	0.7056*	-0.030773	0.003480*	0.004259*	61.0	0.20
CUSTOMER WEIGHTS	-805.3	3.3590	1.8383	0.7210	5.3336	-0.043356	-0.010630*	-0.000807*	77.2	0.29

REGRESSION MODEL: $TWD = b_0 + b_1 \cdot T_{10} + b_2 \cdot T_{50} + b_3 \cdot T_{90} + b_4 \cdot Ta + b_5 \cdot Ta \cdot T_{10} + b_6 \cdot Ta \cdot T_{50} + b_7 \cdot Ta \cdot T_{90}$

* INDICATES COEFFICIENTS NOT SIGNIFICANT AT A 90% CONFIDENCE LEVEL.
** COEFFICIENT OF VARIATION (STANDARD ERROR EXPRESSED AS A PERCENT OF THE MEAN).

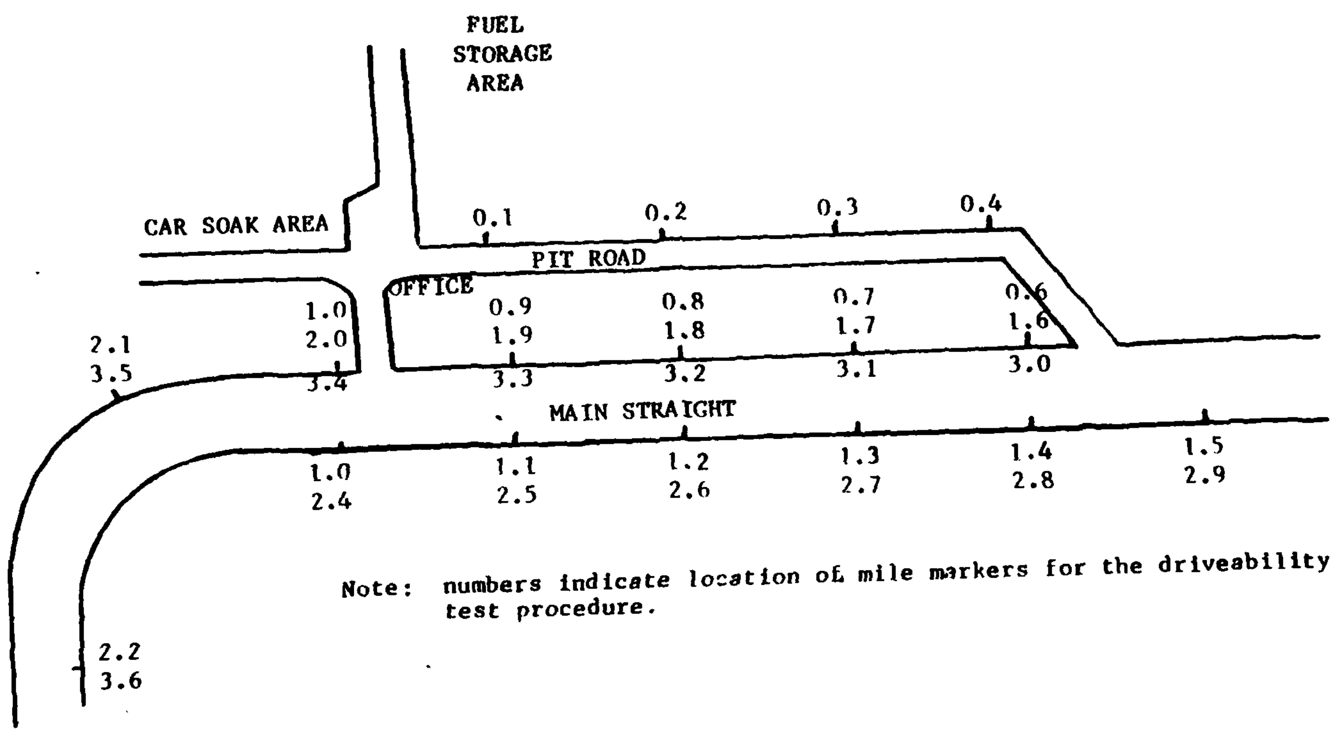
TABLE 15. COMPARISON OF NORMAL AND CUSTOMER DEMERIT SCALE USING NORMALIZED REGRESSION EQUATIONS

DEMERIT SCALE	b_0	b_1	b_2	b_3	c
LOW TEMPERATURE (5.5°F):					
NORMAL	-390.5	0.593	0.327	0.079	3.1455
CUSTOMER	-776.0	0.556	0.317	0.128	5.6169
INTERMEDIATE TEMPERATURE (51.3°F)					
NORMAL	-390.3	0.281	0.492	0.226	2.3958
CUSTOMER	-531.7	0.365	0.416	0.219	3.1073

MODEL: $TWD = b_0 + (b_1 \bullet T_{10} + b_2 \bullet T_{50} + b_3 \bullet T_{90})c$

NOTE: NO RATER ADJUSTMENTS WERE APPLIED TO THESE DATA.

FIGURE 1. LAYOUT OF TEST SITE



Note: numbers indicate location of mile markers for the driveability test procedure.

FIGURE 2. DISTRIBUTION OF AMBIENT TEMPERATURES DURING TEST RUNS

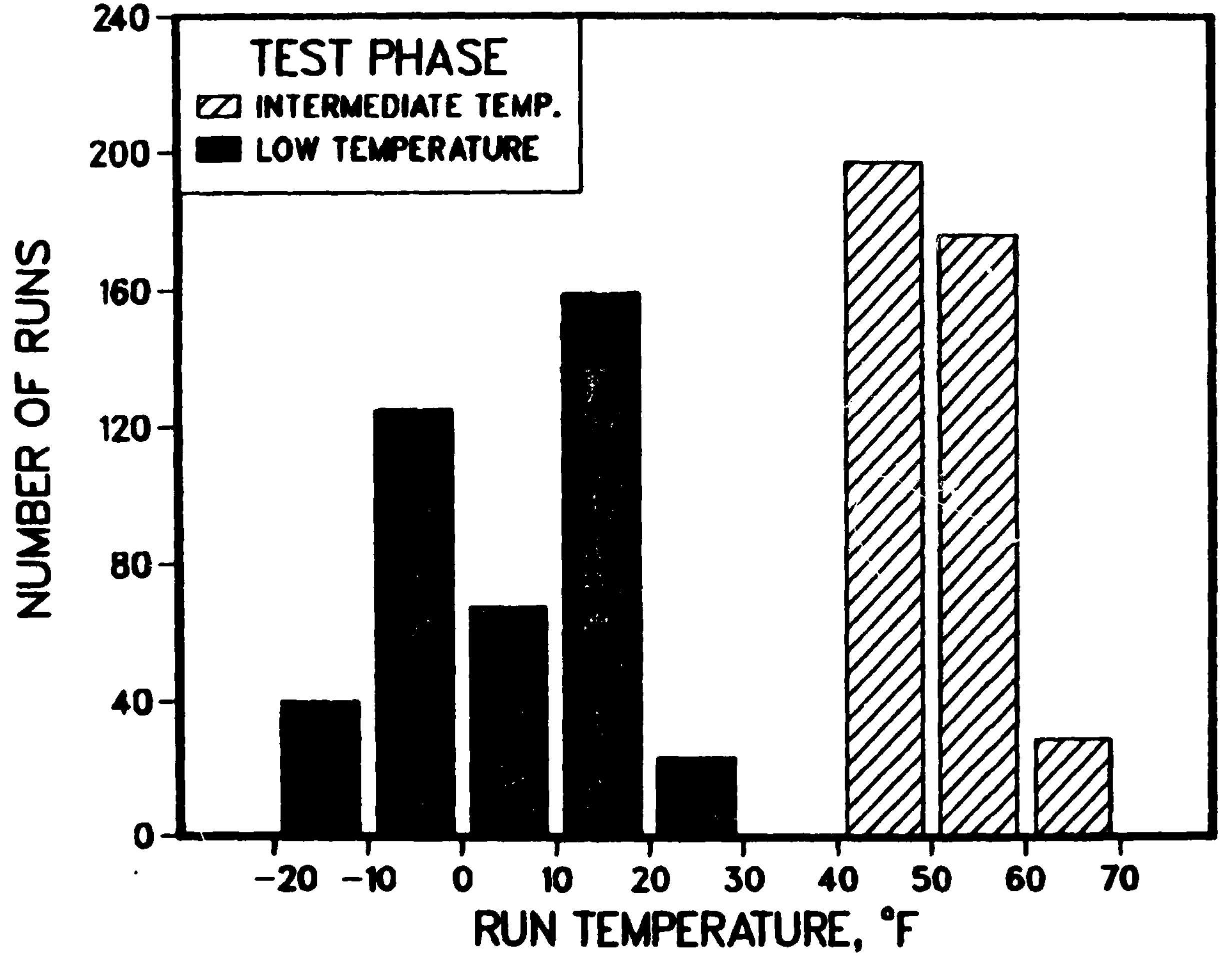
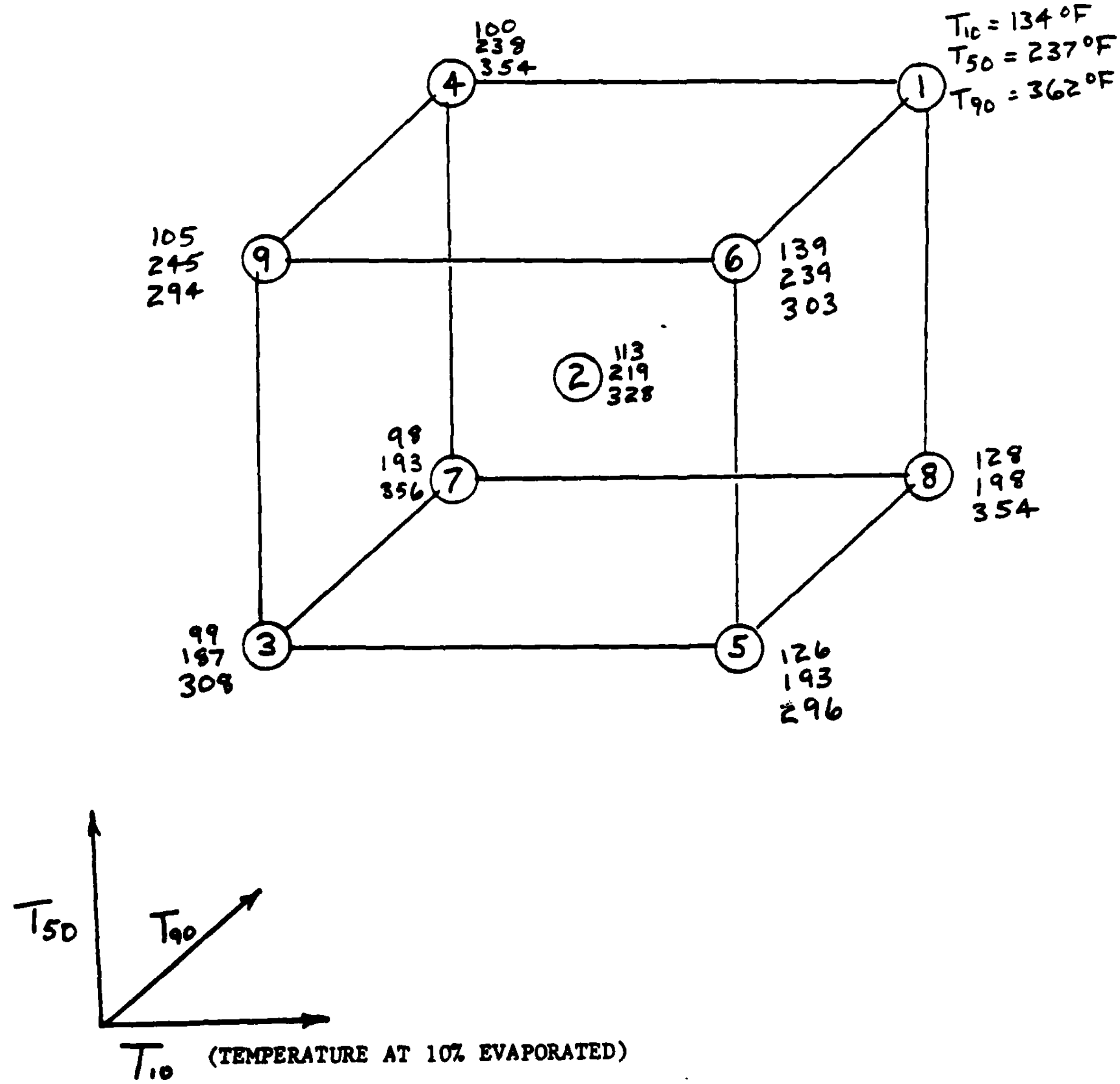


FIGURE 3. EFFORTS TO REMOVE ICE FROM TRACK DURING THE LOW TEMPERATURE PHASE

FIGURE 4. PHOTOGRAPH SHOWING TEST FUEL CAN LOCATION AND COLD STARTING ASSISTANCE

FIGURE 5. TEST FUEL DESIGN



(TEMPERATURE AT 10% EVAPORATED)

FIGURE 6. COMPARISON OF DRIVEABILITY AT LOW AND INTERMEDIATE TEMPERATURES (DATA REPRESENT AVERAGES ACROSS CARS)

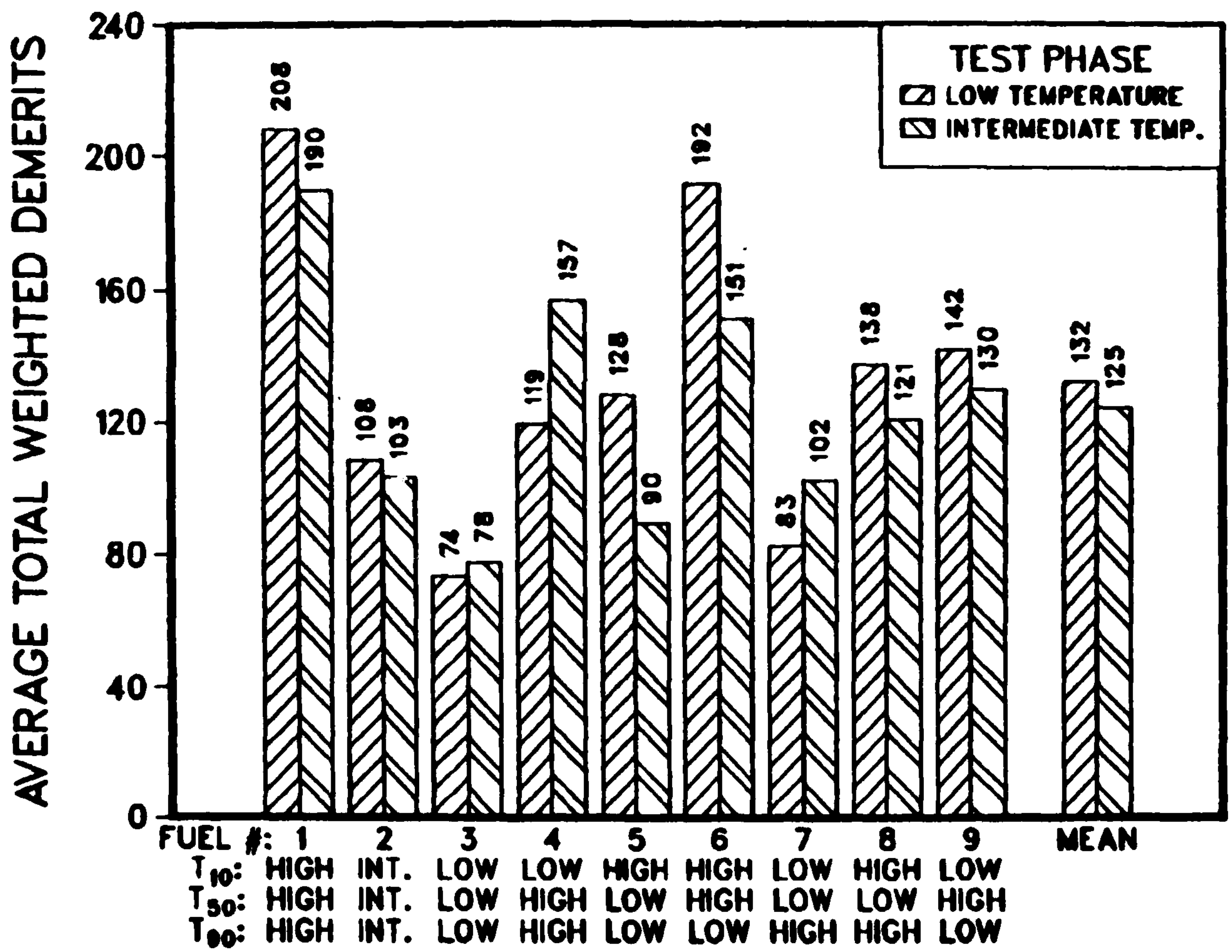


FIGURE 7. EFFECT OF T_{10} ON DRIVEABILITY

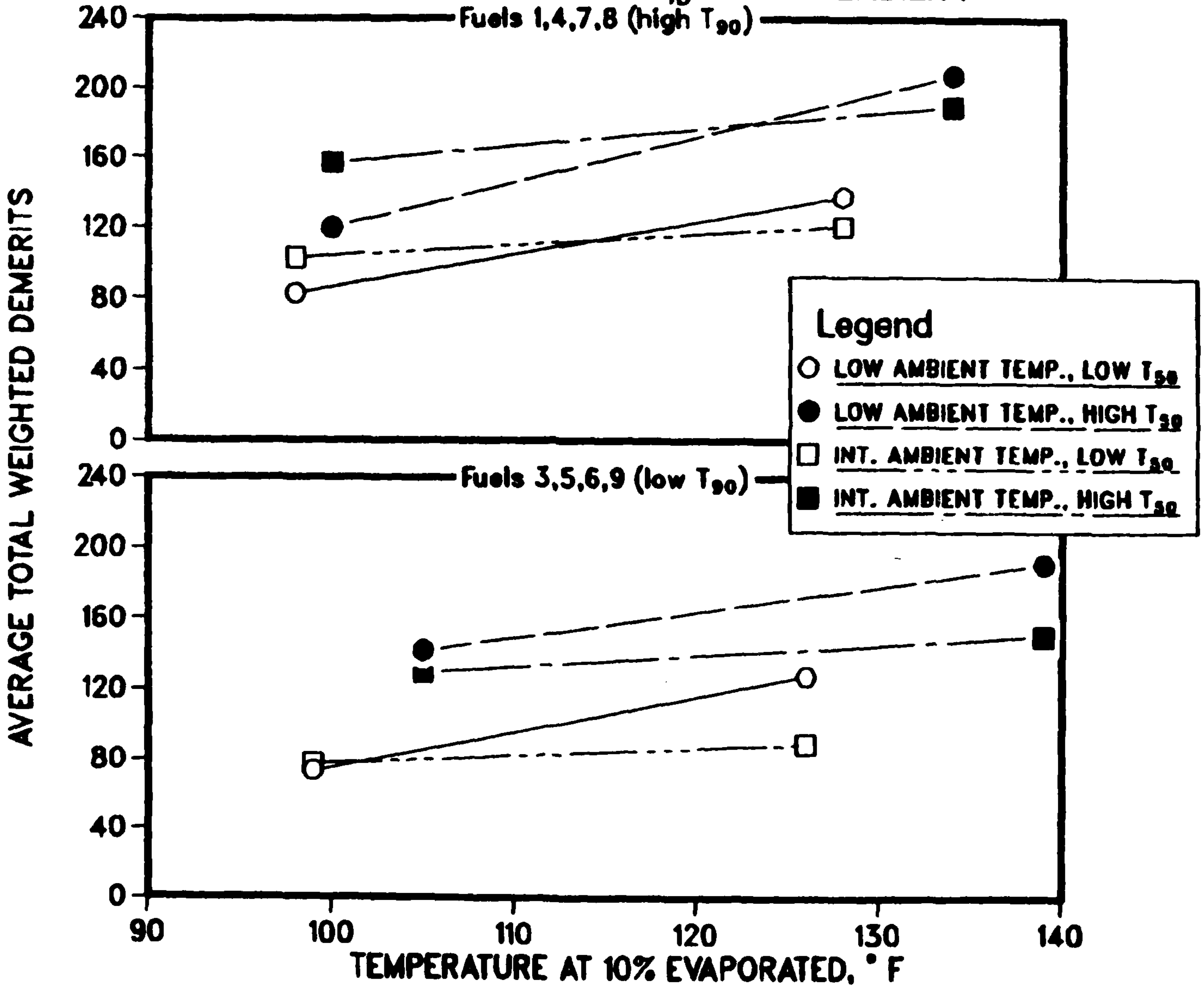


FIGURE 8. COMPARISON OF DRIVEABILITY AT LOW AND INTERMEDIATE TEMPERATURES (DATA REPRESENT AVERAGES ACROSS FUELS)

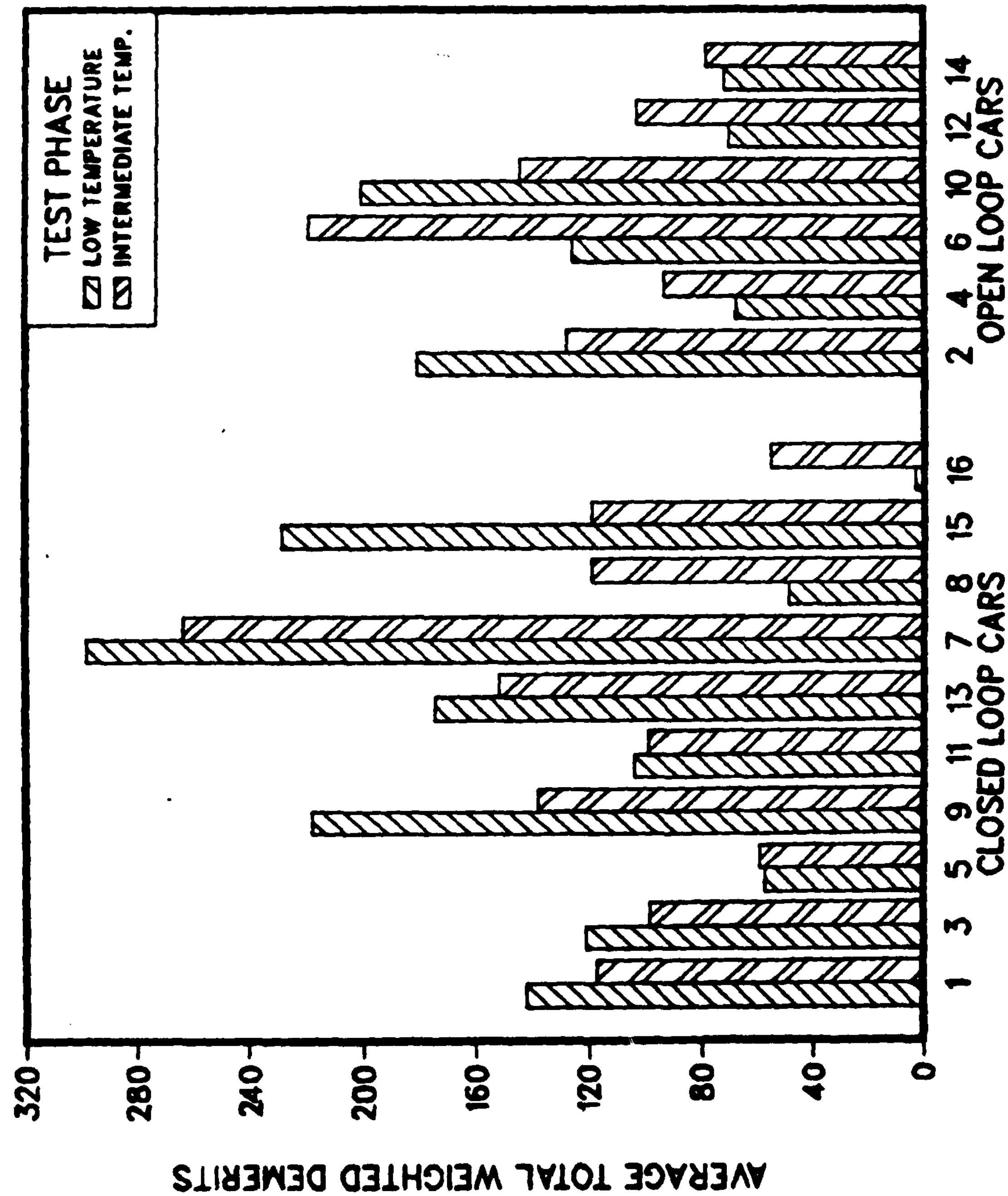


FIGURE 9. COMPARISON OF DATA FOR MATCHED OPEN-LOOP AND CLOSED-LOOP CARS

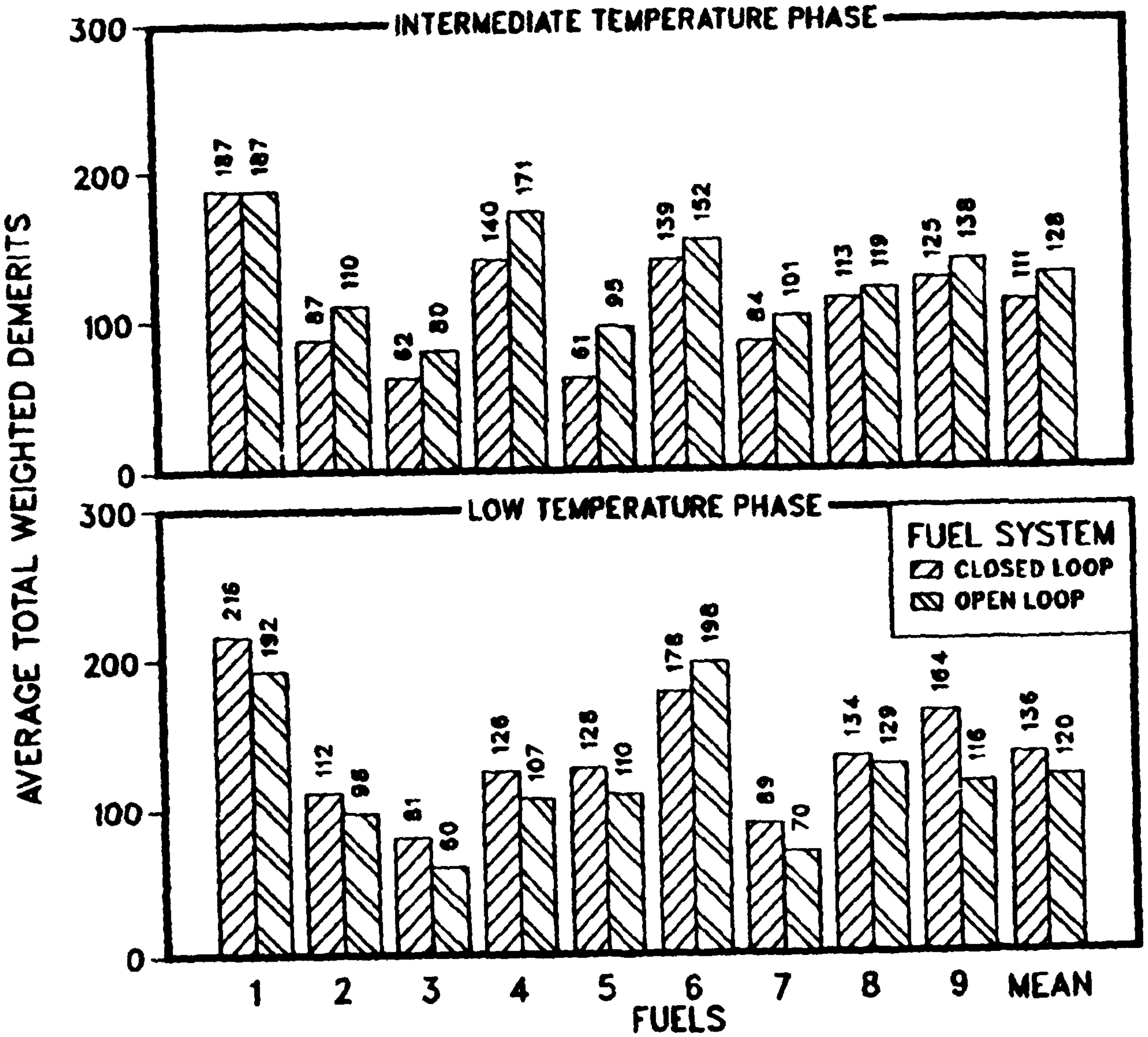


FIGURE 10. COMPARISON OF INTERMEDIATE TEMPERATURE DRIVEABILITY FOR VEHICLES OF VARIOUS MODEL YEARS

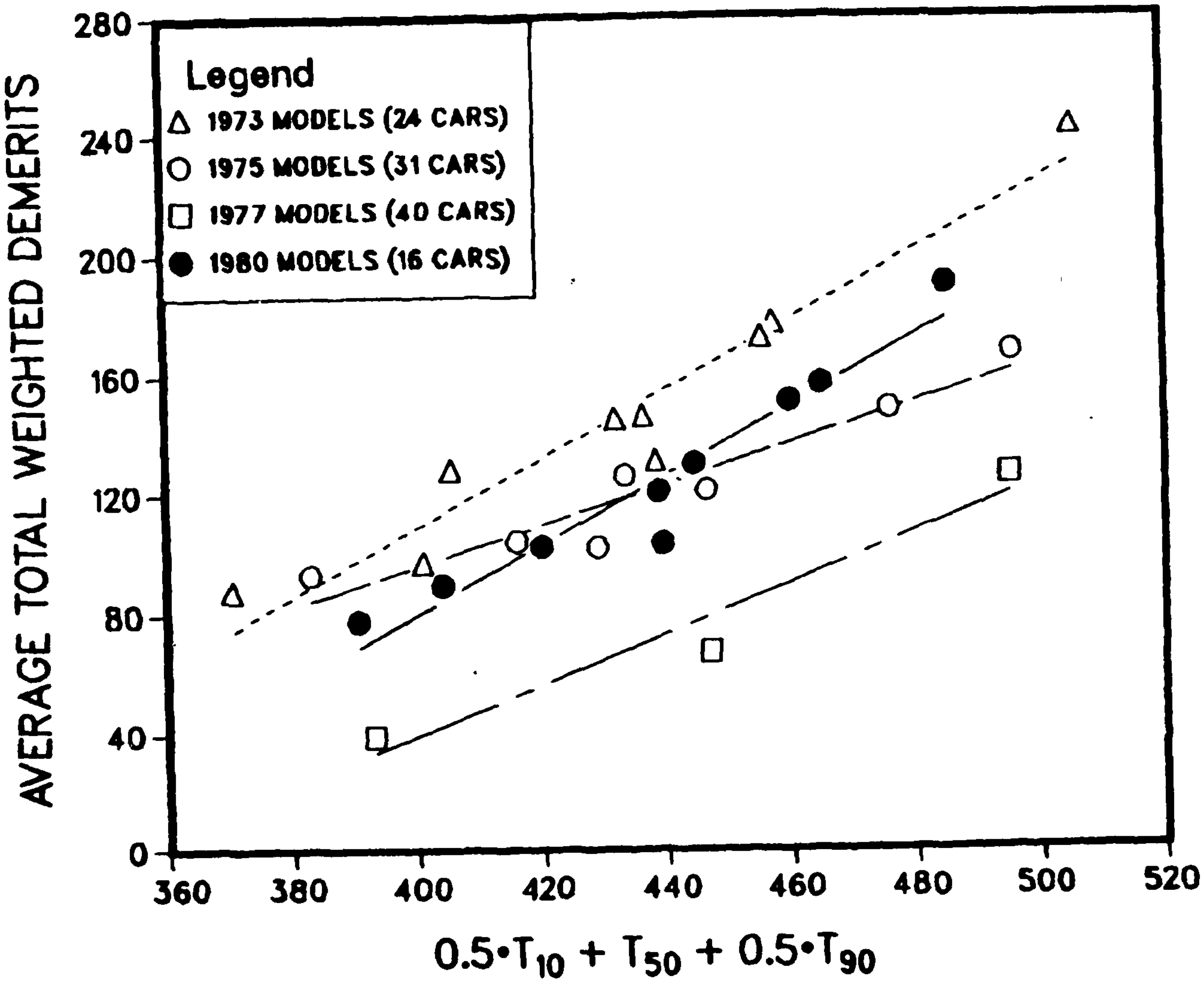


FIGURE 11. COMPARISON OF ACTUAL AND PREDICTED DEMERITS WITH 8-COEFFICIENT REGRESSION MODEL (B)

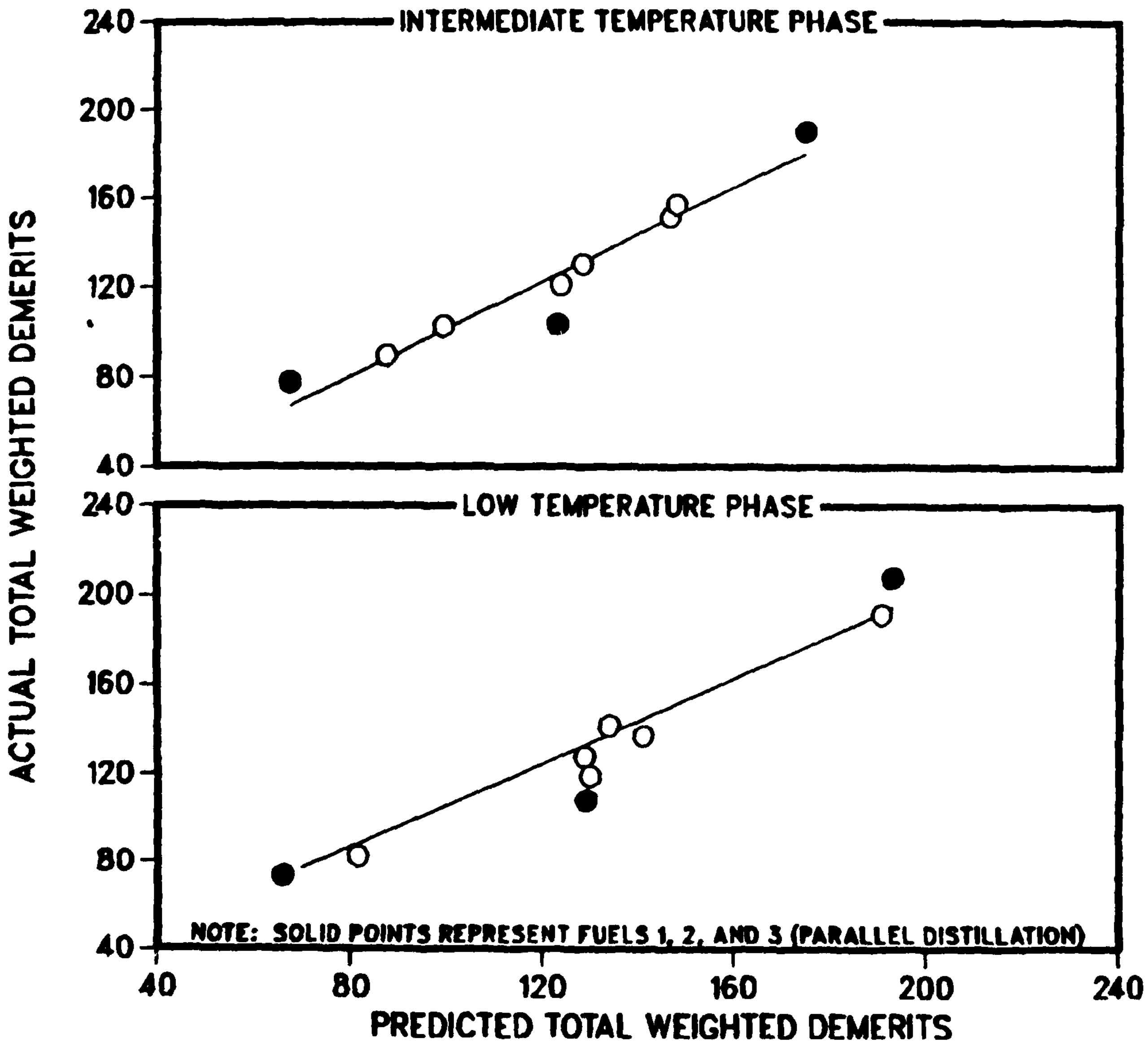


FIGURE 12. COMPARISON OF ACTUAL AND PREDICTED DEMERITS WITH 10-COEFFICIENT REGRESSION MODEL (F)

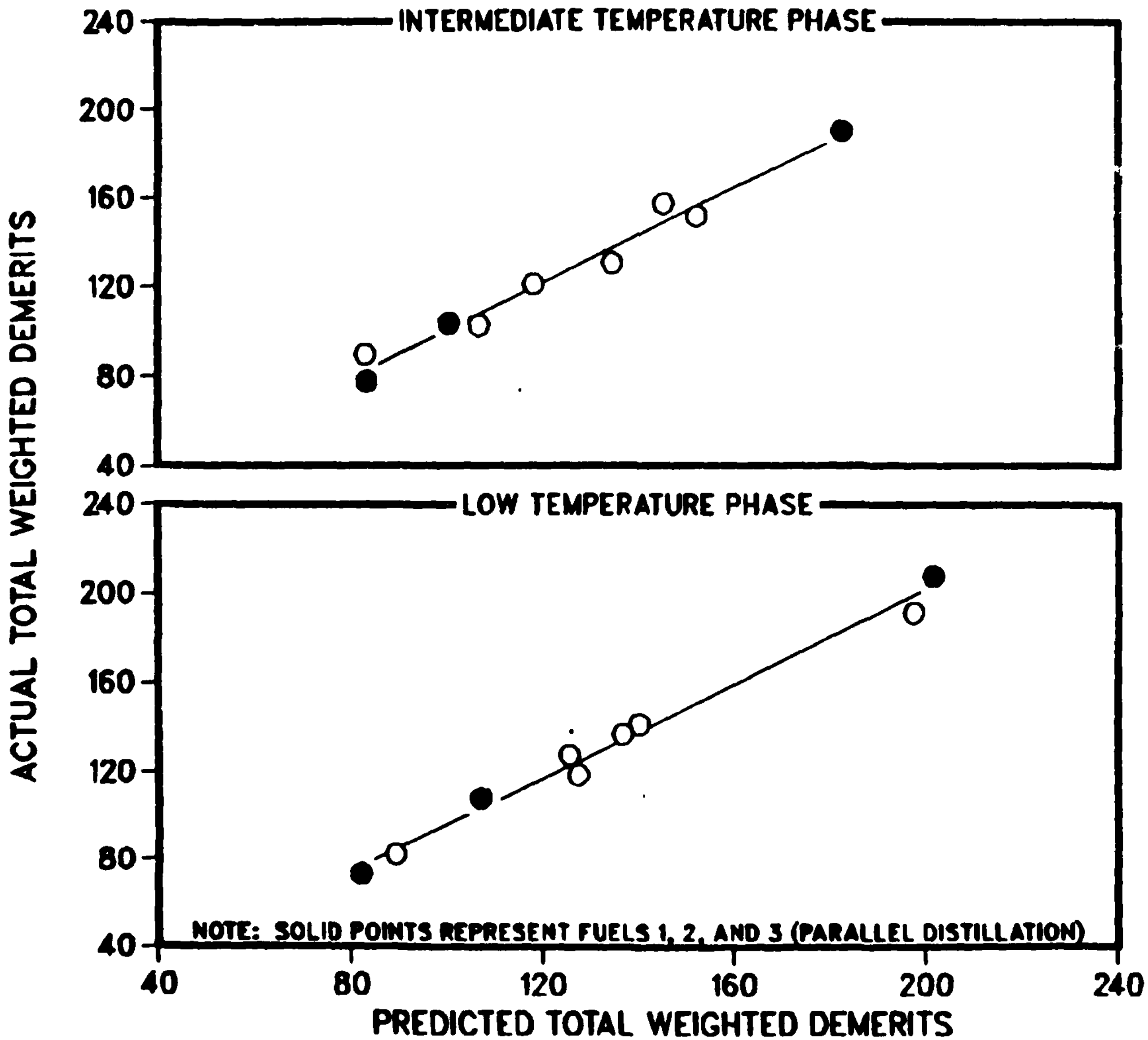


FIGURE 13. EVALUATION OF NONLINEAR EQUATION FOR PREVIOUS MODEL YEARS

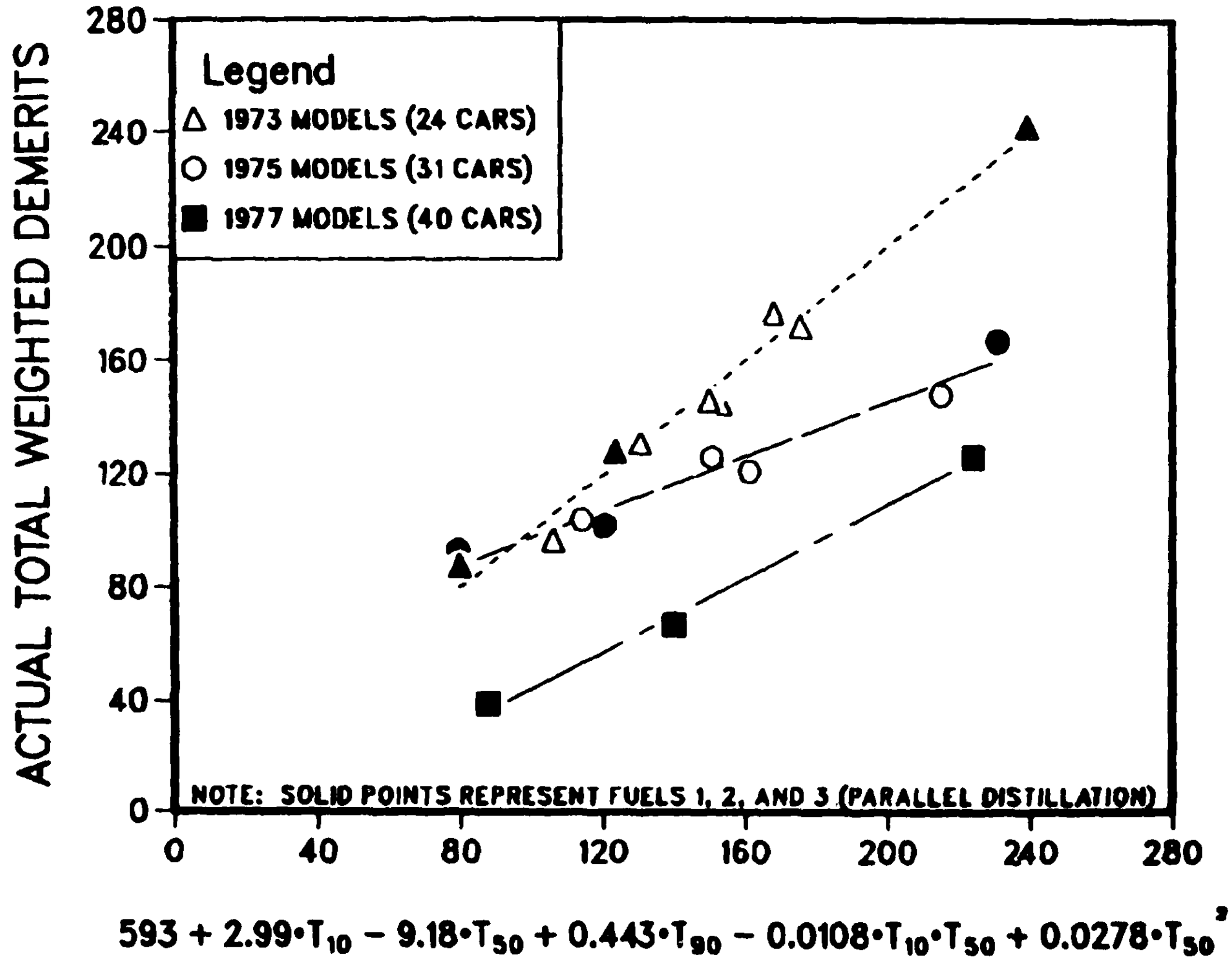
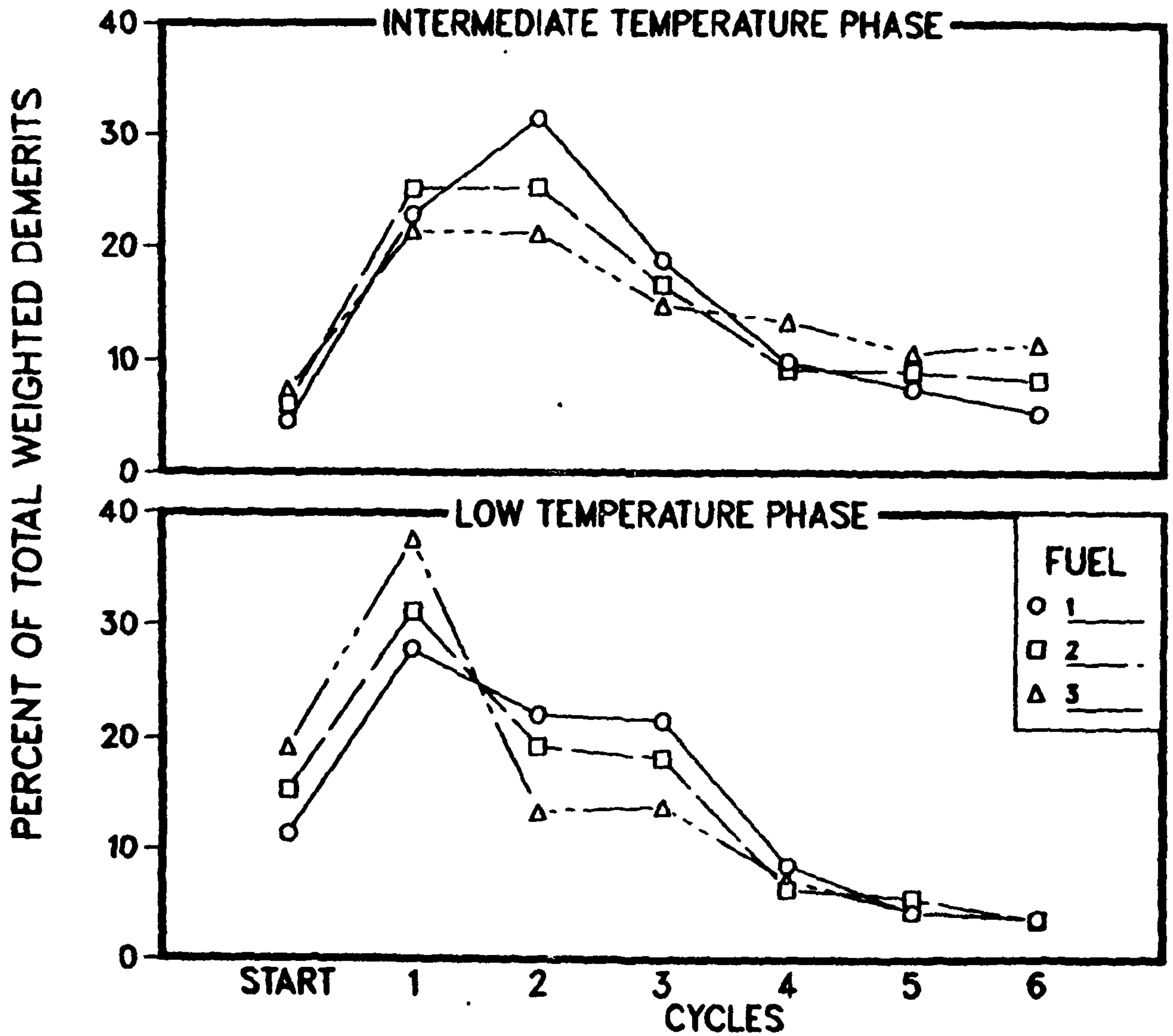


FIGURE 14. DISTRIBUTION OF DEMERITS AMONG TEST CYCLES



APPENDIX A

PROGRAM PARTICIPANTS AND PANEL MEMBERSHIPS

Table A-1. Program Participants

Low Temperature Phase

Name	Company
C. E. (Charley) Baxter*	Mobil Research and Development
N. D. (Norm) Brinkman	General Motors Research Laboratories
G. (Gene) Ellis	Systems Control, Inc.
D. W. (Doug) Hall	Chevron Research Co.
A. (Al) Mallow	Systems Control, Inc.
R. V. (Vance) McCabe	General Motors Research Laboratories
J. D. (Jim) Merrit*	Amoco Oil Co.
W. K. (Bill) Okamoto*	Ford Motor Co.
R. (Dick) Schwartzlander	Gulf Research and Development Co.
J. K. (Ken) Slack*	Suntech, Inc.
F. J. (Fred) Villforth**	Texaco Inc
W. C. (Walt) Williams	Amoco Oil Co.

Intermediate Temperature Phase

Name	Company
C. E. (Charley) Baxter*	Mobil Research and Development
D. W. (Doug) Hall*	Chevron Research Co.
G. S. (George) Hyek*	Gulf Research and Development Co.
W. R. (Bill) Mallett*	Union Oil Co.
J. E. (Jim) Robinson**	Sohio
E. H. (El) Schanerberger*	Ford Motor Co.
E. D. (Lou) Steinke	Suntech, Inc.
B. Y. (Brian) Taniguchi	General Motors Research Laboratories
S. (Sam) Vallas	Amoco Oil Co.

*Rater
**Coordinator

Table A-2. Program Planning and Data Analysis Panel Memberships

Name	Panel Membership: Planning	Analysis*	Company
N. D. Brinkman, Ldr.	X	X	General Motors Research Laboratories
J. H. Baudino	X	X	ARCO Petroleum Products Co.
C. Bello	X	X	Gulf Research and Development Co.
A. M. Horowitz		X	Mobil Research and Development
J. C. Ingamells	X	X	Chevron Research Co.
J. L. Keller	X		Union Oil Co.
W. R. Mallett		X	Union Oil Co.
C. R. Morgan	X		Mobil Research and Development
H. T. Niles	X	X	Ford Motor Co.
R. M. Reuter	X		Texaco Inc
J. E. Robinson	X	X	Sohio
R. T. Simmons	X		Chrysler Corporation
E. D. Steinke	X	X	Suntech, Inc.
F. J. Villforth		X	Texaco Inc
W. C. Williams	X	X	Amoco Oil Co.

*The analysis panel appreciates the contributions of statisticians, G. S. Leithead and h. R. Crawford (Texaco) and J. W. Gorman (Amoco).

A P P E N D I X   B

PROGRAM PROPOSAL AND TEST PROCEDURE DETAILS

PROPOSED CRC PROGRAM

Effect of Fuel Volatility on Driveability of 1980 Cars at Low and Intermediate Ambient Temperatures

Objective

To determine how gasoline volatility affects vehicle driveability at low (0-20°F) and intermediate (40-60°F) ambient temperatures. The test gasolines will be designed to allow independent estimation of front-end, mid-range and tail-end volatility effects, and the test cars will include those with and without closed-loop fuel control systems.

Introduction

Previously, several CRC programs have been conducted to determine the effect of fuel volatility on cold-start/warm-up driveability, but none of these test programs have been run at ambient temperatures below 30°F. A study of fuel volatility effects on low-temperature driveability is desirable in order to aid in the establishment of driveability specifications for fuels marketed at low ambient temperatures.

Starting with the 1980 model year, most cars sold in California are expected to use either a three-way catalyst or a reducing catalyst to control NO_x emissions. These catalysts will also probably be used on cars sold in all states beginning with the 1981 model year. To accommodate these NO_x catalysts, most cars will be equipped with exhaust gas oxygen sensors and closed-loop fuel control systems. These design changes will potentially have a major effect on driveability with various fuels.

This proposed program is designed to measure the effect of several fuel volatility parameters on driveability at low and intermediate ambient temperatures using cars with and without closed-loop fuel control systems. Tests at intermediate as well as at low temperatures are necessary due to the lack of volatility-driveability data for cars with closed-loop fuel control.

Program Summary

A cooperative, cold-start/warm-up driveability program will be conducted during 1980 at Donnybrooke Track near Brainerd, Minnesota. The program will be divided into two 4 1/2-week phases: low temperature tests from January 21 through February 21; and intermediate temperature tests from April 14 through May 15. Sixteen cars, ten with closed-loop and six with open-loop fuel systems, will be tested on nine gasolines designed to provide independent estimation of effects of front-end, mid-range, and tail-end volatility on driveability. The manpower requirement is about 54 man-weeks.

Test Temperatures

Target minimum test temperatures are 0°F (-18°C) and 40°F (4°C) for the low and intermediate temperature phases, respectively. Tests will be conducted as near as possible to these minimum target temperatures, however, due to daily ambient temperature fluctuations, actual ranges of test temperatures will probably be about 0-20°F (-18 to -7°C) for the low temperature phase and about 40-60°F (4-16°C) for the intermediate temperature phase.

Test Location and Timing

The Donnybrooke Track near Brainerd, Minnesota was chosen as the test site because it was the most suitable track found in an area with sufficiently low-ambient temperatures. The track layout is shown in Figure B-1. During late January and early February, ambient temperatures in Brainerd are suitable for the low-temperature phase of the program. A contractor will be hired to remove snow and ice from the track.

The Donnybrooke Track was also chosen for the intermediate-temperature phase of the program to avoid the expense of shipping test cars to an alternative site, and to avoid the potential influence of test track differences on the observed driveability results. Brainerd temperatures are suitable for intermediate temperature testing during late April and early May.

Test Cars

The tests will be conducted with 16 1980 model year cars. The test was limited to 16 cars because 16 was the maximum number which could be tested by the number of participants estimated to be on site at one time. If participation is sufficient, additional cars will be tested in one or both phases. To emphasize future emission hardware, ten of the cars will be equipped with closed-loop fuel systems and six cars with open-loop systems. In general, the closed-loop cars will be California cars and the open-loop cars will be 49-state cars. The ten closed-loop cars will be selected to represent the various types of available engine controls, and the six open-loop cars will be high production cars similar to six of the closed-loop.

Prior to the tests, the cars will be driven a minimum of 500 miles (800 km) and be inspected to insure proper mechanical operation.

Test Fuels

The test fuel design, given in Table B-1, is similar to that for previous CRC programs in which various parts of the distillation curve were varied independently. Fuel 1 and fuels 3 through 9 represent a complete factorial design for two levels of each of the three factors (10, 50, and 90 percent distillation temperature). Fuel 2 is an average volatility fuel included to check for nonlinearity.

The range for each of the three distillation points were chosen to represent the volatility of about 95 percent of commercial gasolines.

In addition, Reid vapor pressure limits have been specified to provide starting at low temperature, and freedom from vapor lock at intermediate temperature.

Test Procedure

The driveability test procedure will be the same as that used in past intermediate-temperature driveability programs. It consists of a cold start (after an overnight soak) followed by 3.6 miles of driving through various maneuvers such as light-throttle acceleration, cruise, detent acceleration, full-throttle acceleration, crowd acceleration, and idle. Starting time is measured and the number of stalls are recorded. Other malfunctions, such as hesitation, stumble, surge, idle roughness, and backfire, are rated subjectively by the driver on a scale of trace, moderate, or heavy. These malfunction observations are converted to demerits to indicate the severity of the driveability problems which were encountered during the test.

Test Design

The test design for the low temperature phase is given in Table B-2 and for the intermediate temperature phase is given in Table B-3. The design provides duplicate tests on all fuels for each phase and additional tests on fuels 1 and 2 for rater comparison and rater repeatability determinations. Test results will be tabulated on site and additional tests will be scheduled, if necessary, to recheck outliers. For each phase there will be four raters with two on site at any given time. This allows the raters to participate in two-week rather than four-week shifts. To provide continuity, at least two of the raters must participate in both phases.

Program Duration and Manpower Requirement

As indicated in Table B-4, each test phase should last about 4 1/2 weeks. Dates selected for the low-temperature phase are January 21 through February 21, 1980, and the intermediate temperature phase from April 14 through May 15, 1980. No company will be expected to participate for the entire nine weeks of both phases. Six participants are required to be on site at all times; this gives a total manpower requirement of 54 man-weeks. Some companies will be asked to provide raters who participate for a total of 4 1/2 weeks (2 1/4 weeks per phase). Others could participate in 2 1/4 week shifts in one or both test phases. Efforts will be made to assign participants to the test phase in which they are most interested.

Supplemental Investigation of Analytical Technique to Measure Fuel Vaporization Rate

Arco has developed a test method [Analytical Chemistry, Vol. 49, pp. 2368-2371 (1977)] to measure the rate of fuel vaporiation under conditions simulating those in an intake manifold. Arco has developed linear relationships between results with this method and driveability demerit results from past CRC programs. As part of their participation in this program, Arco will use this test method to measure vaporization

rates of the test gasolines, and attempt to correlate these measurements with driveability, as measured during both the low and intermediate test phases.

TABLE B-1

Fuel Specifications

Fuel No.	Distillation Temperatures, °F (°C) 10%*	30%**	50%*	70%**	90%**	Reid Vapor Pressure, psi (kPa)
1	130 (54.5)	195 (90.5)	240 (115.5)	290 (143.5)	360 (182.0)	9.0-11.0 (62-76)
2	110 (43.5)	165 (74.0)	215 (101.5)	265 (129.5)	330 (165.5)	10.5-12.5 (72-86)
3	90 (32.0)	135 (57.0)	190 (88.0)	230 (110.0)	300 (149.0)	12.0-14.0 (83-97)
4	90 (32.0)	155 (68.5)	240 (115.5)	290 (143.5)	360 (182.0)	12.0-14.0 (83-97)
5	130 (54.5)	165 (74.0)	190 (88.0)	230 (110.0)	300 (149.0)	9.0-11.0 (62-76)
6	130 (54.5)	195 (90.5)	240 (115.5)	265 (129.5)	300 (149.0)	9.0-11.0 (62-76)
7	90 (32.0)	135 (57.0)	190 (88.0)	265 (129.5)	360 (182.0)	12.0-14.0 (83-97)
8	130 (54.5)	165 (74.0)	190 (88.0)	265 (129.5)	360 (182.0)	9.0-11.0 (62-76)
9	90 (32.0)	155 (68.5)	240 (115.5)	265 (129.5)	300 (149.0)	12.0-14.0 (83-97)

Additional

Minimum Octane Number = 91 RON, 83 MON, 87 $\frac{R+M}{2}$

Benzene Content = 5% maximum

Oxidation Inhibitor = 5 lbs./1000 barrels DuPont No. 31 (or equivalent)

Contaminant Concentrations (maximum) = Pb, 0.05 g/gal
S, 0.04 wt %
P, 0.005 g/gal

* ± 5°F (± 3°C)

** ± 10°F (± 5.5°C)

TABLE B-2

Test Design - Low Temperature Phase

Car No.	Fuel Control System*		Rater Assignments																					
		Test Day:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
		Fuel No.:	5	1	8	4	3	7	2	9	6	1	2	1	2	7	6	8	9	5	3	4	1	2
1	CL		A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	C	C	C	C	C	C	C
2	OL		B	B	B	B	B	B	B	B	B	B	B	D	D	D	D	D	D	D	D	D	D	D
3	CL		A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D	D	D	D
4	OL		B	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C
5	CL		A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	C	C	C	C	C	C	C
6	CL		B	B	B	B	B	B	B	B	B	A	A	D	D	D	D	D	D	D	D	D	C	C
7	OL		A	A	A	A	A	A	A	A	A	B	B	D	D	D	D	D	D	D	D	D	C	C
8	CL		B	B	B	B	B	B	B	B	B	A	A	C	C	C	C	C	C	C	C	C	D	D
		Fuel No.:	8	3	9	1	5	2	4	6	7	2	1	2	1	4	7	9	6	3	5	8	2	1
9	CL		A	A	A	A	A	A	A	A	A	B	B	C	C	C	C	C	C	C	C	C	D	D
10	OL		B	B	B	B	B	B	B	B	B	A	A	C	C	C	C	C	C	C	C	C	D	D
11	CL		A	A	A	A	A	A	A	A	A	B	B	D	D	D	D	D	D	D	D	D	C	C
12	CL		B	B	B	B	B	B	B	B	B	B	B	D	D	D	D	D	D	D	D	D	D	D
13	OL		A	A	A	A	A	A	A	A	A	A	A	C	C	C	C	C	C	C	C	C	C	C
14	CL		B	B	B	B	B	B	B	B	B	B	B	D	D	D	D	D	D	D	D	D	D	D
15	OL		A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D	D	D	D
16	CL		B	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	C

* OL = Open Loop
CL = Closed Loop

TABLE B-3

Test Design - Intermediate Temperature Phase

Car No.	Fuel Control System*		Rater Assignments																					
		Test Day:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
		Fuel No.:	2	8	4	7	9	1	6	3	5	2	1	2	1	9	8	6	7	3	5	4	1	2
1	CL		A	A	A	A	A	A	A	A	A	A	A	E	E	E	E	E	E	E	E	E	E	E
2	OL		F	F	F	F	F	F	F	F	F	F	F	D	D	D	D	D	D	D	D	D	D	D
3	CL		A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D	D	D	D
4	OL		F	F	F	F	F	F	F	F	F	F	F	E	E	E	E	E	E	E	E	E	E	E
5	CL		A	A	A	A	A	A	A	A	A	A	A	E	E	E	E	E	E	E	E	E	E	E
6	CL		F	F	F	F	F	F	F	F	F	A	A	D	D	D	D	D	D	D	D	D	E	E
7	OL		A	A	A	A	A	A	A	A	A	F	F	D	D	D	D	D	D	D	D	D	E	E
8	CL		F	F	F	F	F	F	F	F	F	A	A	E	E	E	E	E	E	E	E	E	D	D
		Fuel No.:	4	9	1	6	8	2	3	5	7	1	2	1	2	4	3	9	6	5	7	8	2	1
9	CL		A	A	A	A	A	A	A	A	A	F	F	E	E	E	E	E	E	E	E	E	D	D
10	OL		F	F	F	F	F	F	F	F	F	A	A	E	E	E	E	E	E	E	E	E	D	D
11	CL		A	A	A	A	A	A	A	A	A	F	F	D	D	D	D	D	D	D	D	D	E	E
12	CL		F	F	F	F	F	F	F	F	F	F	F	D	D	D	D	D	D	D	D	D	D	D
13	OL		A	A	A	A	A	A	A	A	A	A	A	E	E	E	E	E	E	E	E	E	E	E
14	CL		F	F	F	F	F	F	F	F	F	F	F	D	D	D	D	D	D	D	D	D	D	D
15	OL		A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D	D	D	D
16	CL		F	F	F	F	F	F	F	F	F	F	F	E	E	E	E	E	E	E	E	E	E	E

* OL = Open Loop
CL = Closed Loop

TABLE B-4

Estimation of Program Duration and Manpower Requirement

Program Duration

	Days Required Per Test Phase
Preparation and Driver Selection	2
Testing	22
Weekend and Weather Allowance	8
Total Days Per Phase	31 = 4 1/2 weeks

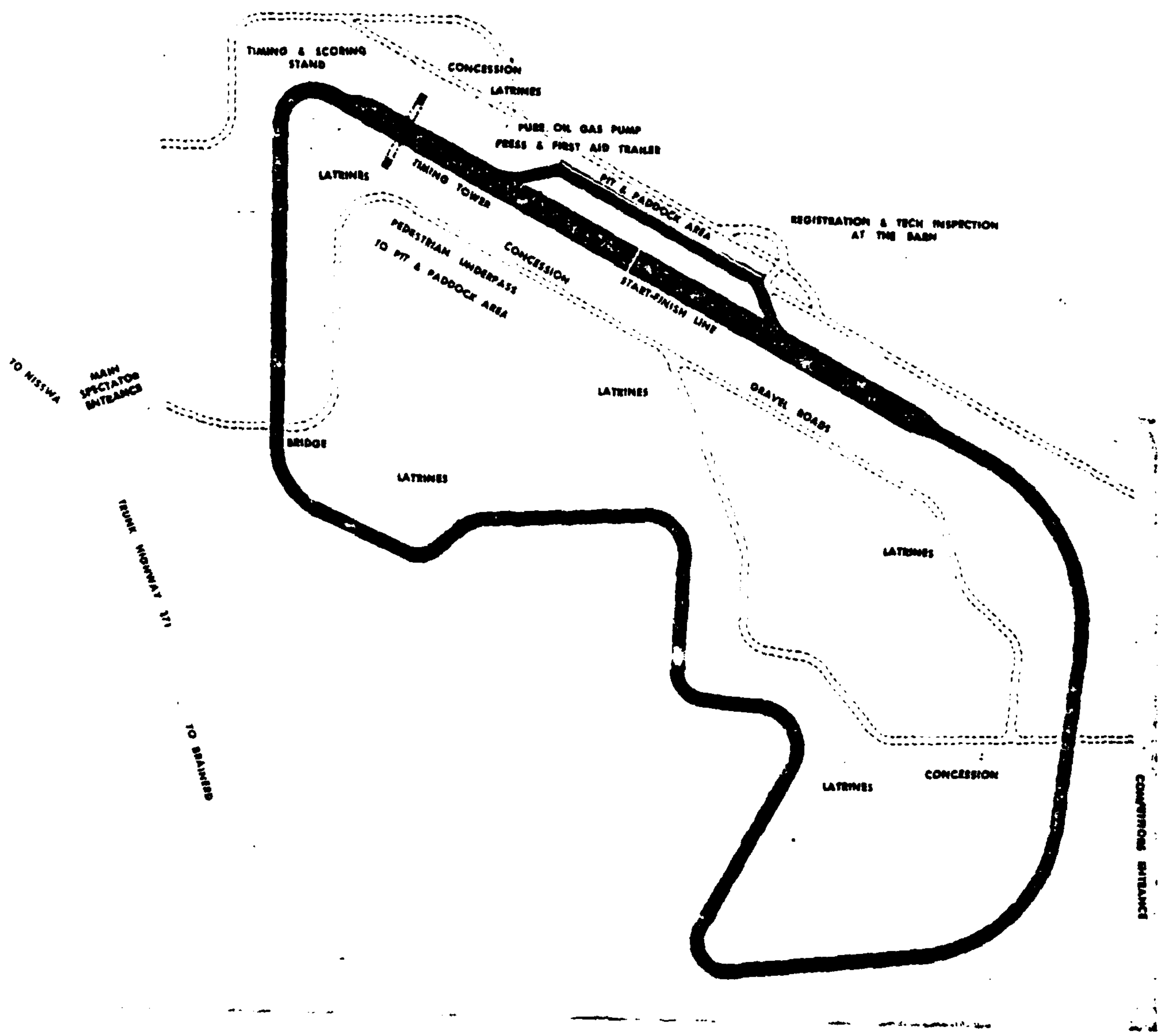
Total for Entire Program = 2 x 4 1/2 weeks = 9 weeks

Manpower Requirement

	Number Required
Raters	2
Observers	2
Fueling and Supervision	1
Data Handling	1
Total	6

Total Manpower Requirement = 6 x 9 = 54 man-weeks

FIGURE B-1



Layout of the 3-Mile Donnybrooke Track

Attachment 1

CRC COLD START AND WARMUP DRIVEABILITY PROCEDURE

TEST PROCEDURE AND DATA RECORDING

A. Record all necessary test information at the top of the data sheet.

B. Start engine per Owner's Manual Procedure. Record start time.

C. If engine fails to start after 15 seconds of cranking, stop cranking and depress accelerator pedal to the floor once and release. Begin cranking and record total cranking time until engine starts.

D. Record idle quality in "Neutral" or "Park" immediately after start; foot should be removed from accelerator pedal.

E. If engine stalls, repeat Steps B and C. Record number of stalls and starting time of required restarts.

F. Allow engine to idle 15 seconds. Apply brakes (right foot), shift to normal drive range, and record idle quality. If engine stalls, restart immediately. Do not record restart time. Record number of stalls. Idle 5 seconds in "Drive."

This completes the start-up portion of the procedure. Note that space on the data sheet has only been provided for two restart times at any idle condition. If three stalls occur at any condition, record the three stalls, restart (without recording time) and proceed to the next scheduled condition.

G. After 5 seconds in "Drive" (Step F), make a light throttle (Lt. th) acceleration from 0-25 mph at constant throttle opening beginning at the predetermined manifold vacuum.* Cruise at 25 mph. At the 0.2 mile marker open throttle to the detent position and accelerate from 25 to 35 mph at constant throttle in high gear. Decelerate to a stop, and at the 0.3 mile marker make a WOT acceleration from 0 to 35 mph. Decelerate to 10 mph and at mile marker 0.4 accelerate at light throttle from 10 to 25 mph. Definitions of light throttle, detent, and WOT accelerations are attached.

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* Marked on vacuum gauge.

H. During the above maneuvers observe and record the severity of any of the following malfunctions(see attached definitions):

1. Hesitation
2. Stumble
3. Surge
4. Stall
5. Backfire

Record maneuvering stalls on the data sheet in the appropriate column: accelerating or decelerating. In addition, measure and record the time required to accelerate from 0-25 on the 0-25 mph maneuver.

I. At the 0.5 mile marker, brake moderately to a stop on the right side of the roadway. Idle for 30 seconds in drive. Record idle quality and number of stalls.

J. Perform Steps G, H, and I three times (1.5 miles). The mile marker for the beginning of each maneuver is indicated on the data sheet.

K. At mile marker 1.5, after completing the 30 second idle, make a crowd acceleration (constant predetermined vacuum) from 0-45 mph. Four-tenths of a mile is provided for this maneuver. Decelerate from 45 to 25 mph at the 1.9 mile marker, and open throttle to detent position and accelerate from 25 to 35 mph. At 2.0 miles decelerate to a stop and accelerate from 10 to 25 mph at light throttle. Rate and record malfunctions in these maneuvers as in Step H. Measure and record the time required to travel the first 0.3 miles of the 0-45 mph crowd maneuver. Idle 30 seconds in drive as in Step I.

L. Perform Step K three times. Appropriate mile markers for the start of each maneuver are shown on the data sheet.

DEFINITIONS AND EXPLANATIONS

Test Run

Operation of a car throughout the prescribed sequence of operating conditions and/or maneuvers for a single test fuel.

Maneuver

A specified single vehicle operation or change of operating conditions (such as idle, acceleration or cruise) that constitutes one segment of the driveability driving schedule.

Cruise

Operation at a prescribed constant vehicle speed with a fixed throttle position on a level road.

Wide Open Throttle (WOT) Acceleration

"Floorboard" acceleration through the gears from prescribed starting speed. Rate at which throttle is depressed is to be as fast as possible without producing tire squeal or appreciable slippage.

Part Throttle (PT) Acceleration

An acceleration made at any defined throttle position, or consistent change in throttle position, less than WOT. Several PT accelerations are used. They are:

1. Light Throttle (Lt th) - All light throttle accelerations are begun by opening the throttle to an initial manifold vacuum and maintaining constant throttle position throughout the remainder of the acceleration. The vacuum selected is one in. Hg greater than the initial power cut-in vacuum obtained from carburetor flow curves. However, if a 0-25 mph light throttle maneuver (car warmed up) cannot be completed in 0.1 mile, vacuum is decreased in steps of one in. Hg until the 0-25 maneuver can be completed in 0.1 mile. The selected vacuum is posted in each car.

2. Crowd - An acceleration made at a constant intake manifold vacuum. To maintain constant vacuum, the throttle opening must be continually increased with increasing engine speed. Crowd accelerations are performed at the same vacuum prescribed for the light throttle acceleration.

3. Detent - All detent accelerations are begun by opening the throttle to the downshift position as indicated by transmission shift characteristic curves. Manifold vacuum corresponding to this point at 25 mph is posted in each car. Constant throttle position is maintained to 35 mph in this maneuver.

Malfunctions

1. Stall

   Any occasion during a test when the engine stops with the ignition on. Three types of stall, indicated by location on the data sheet, are:

   a. Stall; idle - Any stall experienced when the vehicle is not in motion, or when a maneuver is not being attempted.

   b. Stall; maneuvering - Any stall which occurs during a prescribed maneuver or attempt to maneuver.

   c. Stall; decelerating - Any stall which occurs while decelerating between maneuvers.

2. Idle Roughness

   An evaluation of the idle quality or degree of smoothness while the engine is idling.

3. Backfire

   An explosion in the induction or exhaust system.

4. Hesitation

   A temporary lack of vehicle response to opening of the throttle.

5. Stumble

   A short, sharp reduction in acceleration after the vehicle is in motion.

6. Surge

   Cyclic power fluctuations occurring during acceleration or cruise.

Malfunction Severity Ratings

The number of stalls encountered during any maneuver are to be listed in the appropriate data sheet column. Each of the other malfunctions must be rated by severity and the letter designation entered on the data sheet. The following definitions of severity are to be applied in making such ratings:

1. Trace (T) - A level of malfunction severity that is just discernible to a test driver but not to most laymen.

2. Moderate (M) - A level of malfunction severity that is probably noticeable to the average layman.

3. Heavy (H) - A level of malfunction severity that is pronounced and obvious to both test driver and layman.

Enter a T, M or H in the appropriate data block to indicate both the occurrence of the malfunction and its severity. More than one type of malfunction may be recorded on each line. If no malfunctions occur, enter a dash (-) to indicate that the maneuver was performed and operation was satisfactory during that maneuver.

CRC driveability data sheet

Card	Run No.	Car	Fuel	Rater	Date	Time	Temperatures: Soak	Temperatures: Run	Starting Time, sec.: Initial	Restart 1	Restart 2	Restart 3	Idle N.: Ruf Stalls	Idle Dr.: Ruf Stalls
1	2 3 4	5 6 7	8	9	10 11 12	13 14 15 16	17 18	19 20	21 22 23	24 25 26	27 28 29	30 31 32	33 34 35	36 37 38

Card 2 — Run No. 1 2 3 4

	0.0 0-25 Lt. Th.	0.1 25 Cruise	0.2 25-35 Detent	0.3 0-35 WOT	0.4 10-25 Lt. Th.	0.5 Idle
	Hes Stm Srg Bkf Stalls Ac Dc	Hes Stm Srg Bkf Stalls Ac Dc	Hes Stm Srg Bkf Stalls Ac Dc	Hes Stm Srg Bkf Stalls Ac Dc	Hes Stm Srg Bkf Stalls Ac D	Ruf Stalls
	39 40 41 42 43 44	45 46 47 48 49 50	51 52 53 54 55 56	57 58 59 60 61 62	63 64 65 66 67 68	69 70
	0.5	0.6	0.7	0.8	0.9	1.0
	5 6 7 8 9 10	11 12 13 14 15 16	17 18 19 20 21 22	23 24 25 26 27 28	29 30 31 32 33 34	35 36
	1.0	1.1	1.2	1.3	1.4	1.5
	37 38 39 40 41 42	43 44 45 46 47 48	49 50 51 52 53 54	55 56 57 58 59 60	61 62 63 64 65 66	67 68

Card 3 — Run No. 1 2 3 4

Card 4 — Run No. 1 2 3 4

	1.5 0-45 Crowd	1.9 25-35 Detent	2.0 0-35 WOT	2.1 10-25 Lt. Th.	2.2 Idle	
	Hes Stm Srg Bkf Stalls Ac Dc	Hes Stm Srg Bkf Stalls Ac Dc	Hes Stm Srg Bkf Stalls Ac Dc	Hes Stm Srg Bkf Stalls Ac Dc	Ruf Stalls	
Card 3	5 6 7 8 9 10	11 12 13 14 15 16	17 18 19 20 21 22	23 24 25 26 27 28	29 30	
	2.2	2.6	2.7	2.8	2.9	
	31 32 33 34 35 36	37 38 39 40 41 42	43 44 45 46 47 48	49 50 51 52 53 54	55 56	C for Comment
Card 4	2.9	3.3	3.4	3.5	3.6	
	5 6 7 8 9 10	11 12 13 14 15 16	17 18 19 20 21 22	23 24 25 26 27 28	29 30	31

Comments: ______________________________

DEMERIT CALCULATION SYSTEM

A numerical value for driveability during the CRC test is obtained by assigning demerits to operating malfunctions as shown in Table B-5. Depending on the type of malfunction, demerits are assigned in various ways. Demerits for poor starting are obtained by subtracting two seconds from the measured starting time. The number of stalls which occur during idle as well as during driving maneuvers are counted separately and assigned demerits as shown in Table B-5. The multiplying factors of 8 and 32 for idle and maneuvering stalls, respectively, account for the fact that stalls are very undesirable, expecially during car maneuvers. Other malfunctions, such as hesitation, stumble, surge, idle roughness, and backfire, are rated subjectively by the driver on a scale of trace, moderate, or heavy. For these malfunctions, a certain number of demerits is assigned to each of the subjective ratings. However, since all malfunctions are not of equal importance, the demerits are multiplied by the weighting factors shown in Table B-5 to yield weighted demerits. Finally, weighted demerits, demerits for stalls, and demerits for poor starting are summed to obtained total weighted demerits (TWD), which are used as an indication of driveability during the test. As driveability deteriorates, TWD increase.

A restriction has been applied in the totaling of demerits to insure that a stall results in the highest possible number of demerits within a given maneuver. When more than one malfunction occurs during a maneuver, demerits are counted for only the malfunction which had the largest number of weighted demerits. Another restriction was that for each idle period, no more than 3 idle stalls were counted.

TABLE B-5

Method for Calculating Total Weighted Demerits (TWD)

Demerits for Poor Starting:

Demerits = starting time(s) - 2

Demerits for Stalls:

Demerits = (no. of idle stalls) x 8 + (no. of maneuvering stalls) x 32

Demerits for Malfunctions Rated Subjectively:

Demerits for Subjective Ratings

Trace	= 1
Moderate	= 2
Heavy	= 4

Weighting Factors for Each Malfunction

Idle Roughness	= 1
Surge	= 4
Backfire, Stumble, Hesitation	= 6

Weighted Demerits = Demerits x Weighting Factor

Calculation:

Total Weighted Demerits = Weighted Demerits + Demerits for Stalls + Demerits for Poor Starting

Note: When more than one malfunction occurs in a driving maneuver, only the malfunction giving the highest weighted demerits is counted.

ON-SITE CAR PREPARATION SCHEDULE

a. Install vacuum gauges in cars.

b. Drive cars to determine light-throttle and detent vacuums to be used for tests.

Light-throttle vacuum: This vacuum will be determined by performing accelerations from 0 to 25 mph. Warm up the car first. Then select a vacuum, start the acceleration from 0 at this vacuum, and maintain constant throttle position. Repeat until a vacuum is found which allows a 0 to 25 mph acceleration to be made in 0.05 to 0.1 miles. Mark this vacuum on vacuum gauge.

Detent vacuum: Cruise at 25 mph. Open the throttle to a preselected vacuum and determine if a downshift has occurred. Repeat to find the minimum vacuum level which can be achieved without a downshift. The vacuum for the detent acceleration should be 1 in. Hg above this minimum vacuum. Mark on vacuum gauge.

c. Install identifying numbers on cars and fuel cans.

A P P E N D I X   C

DATA LISTING

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IWD	ADJ. IWD
LOW TEMP.	1	1	1	A	153	202	-16	-13	256	273
LOW TEMP.	1	1	1	A	22	125	-9	0	185	202
LOW TEMP.	1	1	2	C	406	224	8	12	271	240
LOW TEMP.	1	1	2	C	385	219	9	28	254	223
LOW TEMP.	1	1	2	C	225	208	10	14	147	116
LOW TEMP.	1	2	1	A	170	204	-4	11	130	147
LOW TEMP.	1	2	1	A	69	128	-26	-6	112	129
LOW TEMP.	1	2	2	C	391	223	11	11	161	130
LOW TEMP.	1	2	2	C	249	209	4	8	124	93
LOW TEMP.	1	3	1	A	138	201	-19	-12	65	82
LOW TEMP.	1	3	2	C	352	215	-3	3	120	89
LOW TEMP.	1	4	1	A	113	131	-25	-7	142	159
LOW TEMP.	1	4	2	C	360	218	8	16	206	175
LOW TEMP.	1	5	1	A	218	207	14	17	97	114
LOW TEMP.	1	5	1	A	9	129	-29	-12	154	171
LOW TEMP.	1	5	2	C	326	214	-14	0	171	140
LOW TEMP.	1	6	1	A	181	205	16	20	172	189
LOW TEMP.	1	6	1	A	14	124	1	13	115	132
LOW TEMP.	1	6	2	C	278	211	0	15	168	137
LOW TEMP.	1	7	1	A	40	126	-24	-10	134	151
LOW TEMP.	1	7	2	C	268	210	11	15	102	71
LOW TEMP.	1	8	1	A	202	206	-3	1	154	171
LOW TEMP.	1	8	1	A	102	130	-15	-2	131	148
LOW TEMP.	1	8	2	C	296	212	-13	5	185	154
LOW TEMP.	1	9	1	A	58	127	-18	-8	159	176
LOW TEMP.	1	9	2	C	311	213	-6	16	120	89
LOW TEMP.	2	1	1	B	192	205	16	20	199	183
LOW TEMP.	2	1	1	B	152	202	-16	-5	278	262
LOW TEMP.	2	1	1	B	32	125	-9	1	209	193
LOW TEMP.	2	1	2	D	417	224	8	12	235	234
LOW TEMP.	2	1	2	D	377	219	9	28	219	218
LOW TEMP.	2	1	2	D	235	208	10	15	195	194
LOW TEMP.	2	2	1	B	168	204	-4	11	173	157
LOW TEMP.	2	2	1	B	73	128	-26	-2	232	216
LOW TEMP.	2	2	2	D	399	223	11	11	133	132
LOW TEMP.	2	2	2	D	243	209	4	8	162	161
LOW TEMP.	2	3	1	B	200	206	-3	2	151	135
LOW TEMP.	2	3	1	B	136	201	-19	-12	262	246
LOW TEMP.	2	3	2	D	345	215	-3	4	115	114
LOW TEMP.	2	4	1	B	211	207	14	18	108	92
LOW TEMP.	2	4	1	B	128	131	-25	2	223	207
LOW TEMP.	2	4	2	D	369	218	8	16	219	218
LOW TEMP.	2	5	1	B	88	129	-29	-8	127	111
LOW TEMP.	2	5	2	D	336	214	-14	3	171	170
LOW TEMP.	2	6	1	B	1	124	1	13	424	408
LOW TEMP.	2	6	2	D	285	211	0	15	190	189
LOW TEMP.	2	7	1	B	48	126	-24	-4	107	91
LOW TEMP.	2	7	2	D	260	210	11	16	115	114
LOW TEMP.	2	8	1	B	105	130	-15	-5	263	247
LOW TEMP.	2	8	2	D	302	212	-13	2	187	186
LOW TEMP.	2	9	1	B	49	127	-18	-6	212	196
LOW TEMP.	2	9	2	D	321	213	-6	16	115	114

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW TWD	ADJ. TWD
LOW TEMP.	3	1	1	A	154	202	-16	-12	375	392
LOW TEMP.	3	1	1	A	23	125	-9	1	270	287
LOW TEMP.	3	1	2	C	402	224	8	8	226	195
LOW TEMP.	3	1	2	C	379	219	9	26	178	147
LOW TEMP.	3	1	2	D	236	208	10	15	174	173
LOW TEMP.	3	2	1	A	169	204	-4	10	69	86
LOW TEMP.	3	2	1	A	65	128	-26	-8	57	74
LOW TEMP.	3	2	2	C	386	223	11	11	77	46
LOW TEMP.	3	2	2	D	244	209	4	8	61	60
LOW TEMP.	3	3	1	A	142	201	-19	-6	16	33
LOW TEMP.	3	3	2	D	338	215	-3	-2	20	19
LOW TEMP.	3	4	1	A	120	131	-25	2	109	126
LOW TEMP.	3	4	2	D	362	218	8	12	119	118
LOW TEMP.	3	5	1	A	94	129	-29	-10	44	61
LOW TEMP.	3	5	2	D	331	214	-14	-3	157	156
LOW TEMP.	3	6	1	A	203	206	-3	2	154	171
LOW TEMP.	3	6	1	A	16	124	1	14	144	161
LOW TEMP.	3	6	2	D	284	211	0	14	120	119
LOW TEMP.	3	7	1	A	219	207	14	17	12	29
LOW TEMP.	3	7	1	A	37	126	-24	-13	195	212
LOW TEMP.	3	7	2	D	261	210	11	17	6	5
LOW TEMP.	3	8	1	A	182	205	16	22	45	62
LOW TEMP.	3	8	1	A	101	130	-15	-2	107	124
LOW TEMP.	3	8	2	D	300	212	-13	-2	141	140
LOW TEMP.	3	9	1	A	60	127	-18	-7	280	297
LOW TEMP.	3	9	2	D	315	213	-6	13	87	86
LOW TEMP.	4	1	1	B	191	205	16	22	63	47
LOW TEMP.	4	1	1	B	151	202	-16	-12	227	211
LOW TEMP.	4	1	1	B	31	125	-9	1	189	173
LOW TEMP.	4	1	2	C	403	224	8	8	174	143
LOW TEMP.	4	1	2	C	382	219	9	27	125	94
LOW TEMP.	4	1	2	C	226	208	10	14	89	58
LOW TEMP.	4	2	1	B	161	204	-4	10	83	67
LOW TEMP.	4	2	1	B	75	128	-26	-6	98	82
LOW TEMP.	4	2	2	C	387	223	11	11	104	73
LOW TEMP.	4	2	2	C	250	209	4	8	26	-5
LOW TEMP.	4	3	1	B	130	201	-19	-8	28	12
LOW TEMP.	4	3	2	C	347	215	-3	0	25	-6
LOW TEMP.	4	4	1	B	127	131	-25	0	110	94
LOW TEMP.	4	4	2	C	355	218	8	13	97	66
LOW TEMP.	4	5	1	B	87	129	-29	-10	24	8
LOW TEMP.	4	5	2	C	322	214	-14	-7	130	99
LOW TEMP.	4	6	1	B	2	124	1	12	229	213
LOW TEMP.	4	6	2	C	275	211	0	13	142	111
LOW TEMP	4	7	1	B	209	207	14	16	37	21
LOW TEMP.	4	7	1	B	47	126	-24	-11	65	49
LOW TEMP.	4	7	2	C	266	210	11	15	16	-15
LOW TEMP	4	8	1	B	199	206	-3	1	154	138
LOW TEMP	4	8	1	B	106	130	-15	-3	67	51
LOW TEMP	4	8	2	C	290	212	-13	-6	139	108
LOW TEMP	4	9	1	B	53	127	18	-8	39	23
LOW TEMP	4	9	2	C	305	213	-6	13	74	43

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IUD	ADJ. IUD
LOW TEMP.	5	1	1	A	19	125	-9	-3	181	198
LOW TEMP.	5	1	1	B	148	202	-16	0	41	25
LOW TEMP.	5	1	2	C	228	208	10	15	112	81
LOW TEMP.	5	1	2	D	415	224	8	11	195	194
LOW TEMP.	5	1	2	D	372	219	9	26	67	66
LOW TEMP.	5	2	1	A	67	128	-26	-7	33	50
LOW TEMP.	5	2	1	B	166	204	-4	14	26	10
LOW TEMP.	5	2	2	C	252	209	4	8	61	30
LOW TEMP.	5	2	2	D	400	223	11	12	43	42
LOW TEMP.	5	3	1	A	144	201	-19	-5	33	50
LOW TEMP.	5	3	2	C	353	215	-3	4	34	3
LOW TEMP.	5	4	1	A	118	131	-25	0	70	87
LOW TEMP.	5	4	2	C	361	218	8	16	45	14
LOW TEMP.	5	5	1	A	95	129	-29	-10	32	49
LOW TEMP.	5	5	2	C	329	214	-14	-4	66	35
LOW TEMP.	5	6	1	A	183	205	16	22	77	94
LOW TEMP.	5	6	1	A	11	124	1	12	89	106
LOW TEMP.	5	6	2	C	279	211	0	16	132	101
LOW TEMP.	5	7	1	A	204	206	-3	3	37	54
LOW TEMP.	5	7	1	A	35	126	-24	-13	94	111
LOW TEMP.	5	7	2	C	269	210	11	17	1	-30
LOW TEMP.	5	8	1	A	99	130	-15	-3	51	68
LOW TEMP.	5	8	2	C	295	212	-13	2	122	91
LOW TEMP.	5	9	1	A	220	207	14	19	65	82
LOW TEMP.	5	9	1	A	62	127	-18	-4	43	60
LOW TEMP.	5	9	2	C	312	213	-6	16	62	31
LOW TEMP.	6	1	1	A	155	202	-16	-9	173	190
LOW TEMP.	6	1	1	B	190	205	16	22	216	200
LOW TEMP.	6	1	1	B	30	125	-9	0	109	93
LOW TEMP.	6	1	2	C	409	224	8	12	308	277
LOW TEMP.	6	1	2	C	383	219	9	28	272	241
LOW TEMP.	6	1	2	D	234	208	10	14	200	199
LOW TEMP.	6	2	1	A	173	204	-4	12	47	64
LOW TEMP.	6	2	1	B	76	128	-26	-7	62	46
LOW TEMP.	6	2	2	C	389	223	11	11	163	132
LOW TEMP.	6	2	2	D	241	209	4	8	74	73
LOW TEMP.	6	3	1	B	134	201	-19	-4	3	-13
LOW TEMP.	6	3	2	D	340	215	-3	0	110	109
LOW TEMP.	6	4	1	B	126	131	-25	0	87	71
LOW TEMP.	6	4	2	D	364	218	8	13	124	123
LOW TEMP.	6	5	1	B	86	129	-29	-10	114	98
LOW TEMP.	6	5	2	D	332	214	-14	-2	209	208
LOW TEMP.	6	6	1	B	198	206	-3	1	251	235
LOW TEMP.	6	6	1	B	3	124	1	13	360	344
LOW TEMP.	6	6	2	D	281	211	0	11	191	190
LOW TEMP.	6	7	1	B	46	126	-24	-13	57	41
LOW TEMP.	6	7	2	D	257	210	11	14	95	94
LOW TEMP.	6	8	1	B	107	130	-15	-3	175	159
LOW TEMP.	6	8	2	D	297	212	-13	-8	154	153
LOW TEMP.	6	9	1	B	210	207	14	17	117	101
LOW TEMP.	6	9	1	B	52	127	-18	-8	55	39
LOW TEMP.	6	9	2	D	314	213	-6	12	122	121

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW TWD	ADJ. TWD
LOW TEMP.	7	1	1	A	24	125	-9	1	307	324
LOW TEMP.	7	1	1	B	150	202	-16	-4	514	493
LOW TEMP.	7	1	2	C	408	224	8	12	508	477
LOW TEMP.	7	1	2	C	380	219	9	26	456	425
LOW TEMP.	7	1	2	D	233	208	10	14	383	382
LOW TEMP.	7	2	1	A	71	128	-26	-5	208	225
LOW TEMP.	7	2	1	B	165	204	-4	12	358	342
LOW TEMP.	7	2	2	C	393	223	11	12	334	303
LOW TEMP.	7	2	2	D	242	209	4	8	324	323
LOW TEMP.	7	3	1	A	201	206	-3	1	162	179
LOW TEMP.	7	3	1	A	184	205	16	22	160	177
LOW TEMP.	7	3	1	A	141	201	-19	-7	241	258
LOW TEMP.	7	3	2	D	339	215	-3	0	260	259
LOW TEMP.	7	4	1	A	119	131	-25	0	297	314
LOW TEMP.	7	4	2	D	363	218	8	13	283	282
LOW TEMP.	7	5	1	A	89	129	-29	-15	152	169
LOW TEMP.	7	5	2	D	330	214	-14	-7	419	418
LOW TEMP.	7	6	1	A	15	124	1	14	228	245
LOW TEMP.	7	6	2	D	282	211	0	11	383	382
LOW TEMP.	7	7	1	A	217	207	14	16	187	204
LOW TEMP.	7	7	1	A	38	126	-24	-13	280	297
LOW TEMP.	7	7	2	D	258	210	11	15	261	260
LOW TEMP.	7	8	1	A	97	130	-15	-5	283	300
LOW TEMP.	7	8	2	D	298	212	-13	-6	361	360
LOW TEMP.	7	9	1	A	57	127	-18	-10	168	185
LOW TEMP.	7	9	2	D	313	213	-6	13	300	299
LOW TEMP.	8	1	1	A	160	202	-16	0	75	92
LOW TEMP.	8	1	1	B	189	205	16	22	82	66
LOW TEMP.	8	1	1	B	29	125	-9	-1	90	74
LOW TEMP.	8	1	2	C	229	208	10	17	68	37
LOW TEMP.	8	1	2	D	410	224	8	8	127	126
LOW TEMP.	8	1	2	D	370	219	9	26	90	89
LOW TEMP.	8	2	1	A	176	204	-4	14	51	68
LOW TEMP.	8	2	1	B	77	128	-26	-6	49	33
LOW TEMP.	8	2	2	C	253	209	4	8	16	-15
LOW TEMP.	8	2	2	D	395	223	11	11	56	55
LOW TEMP.	8	3	1	B	133	201	-19	-5	26	10
LOW TEMP.	8	3	2	C	348	215	-3	0	78	47
LOW TEMP.	8	4	1	B	125	131	-25	-6	58	42
LOW TEMP.	8	4	2	C	356	218	8	13	85	54
LOW TEMP.	8	5	1	B	85	129	-29	-11	34	18
LOW TEMP.	8	5	2	C	327	214	-14	3	89	58
LOW TEMP.	8	6	1	B	213	207	14	20	66	50
LOW TEMP.	8	6	1	B	4	124	1	13	202	186
LOW TEMP.	8	6	2	C	277	211	0	15	106	75
LOW TEMP.	8	7	1	B	45	126	-24	-13	33	17
LOW TEMP.	8	7	2	C	270	210	11	17	51	20
LOW TEMP.	8	8	1	B	108	130	-15	-2	62	46
LOW TEMP.	8	8	2	C	294	212	-13	1	90	59
LOW TEMP.	8	9	1	B	197	206	-3	3	75	59
LOW TEMP.	8	9	1	B	51	127	-18	-10	25	9
LOW TEMP.	8	9	2	C	310	213	-6	15	93	62

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW TWD	ADJ. TWD
LOW TEMP.	9	1	1	A	98	130	-15	-5	270	287
LOW TEMP.	9	1	1	B	164	204	-4	11	318	302
LOW TEMP.	9	1	2	C	254	209	4	9	287	256
LOW TEMP.	9	1	2	D	397	223	11	11	301	300
LOW TEMP.	9	2	1	A	39	126	-24	-11	217	234
LOW TEMP.	9	2	1	B	149	202	-16	-9	250	234
LOW TEMP.	9	2	2	C	230	203	10	19	80	49
LOW TEMP.	9	2	2	D	414	224	8	11	172	171
LOW TEMP.	9	2	2	D	373	219	9	27	128	127
LOW TEMP.	9	3	1	A	117	131	-25	-6	102	119
LOW TEMP.	9	3	2	C	323	214	-14	-3	180	149
LOW TEMP.	9	4	1	A	223	207	14	20	157	174
LOW TEMP.	9	4	1	A	21	125	-9	-1	173	190
LOW TEMP.	9	4	2	C	271	210	11	18	198	167
LOW TEMP.	9	5	1	A	207	206	-3	7	143	[illegible]
LOW TEMP.	9	5	1	A	137	201	-19	-12	228	245
LOW TEMP.	9	5	1	A	59	127	-18	-7	216	233
LOW TEMP.	9	5	2	C	349	215	-3	2	311	280
LOW TEMP.	9	6	1	A	68	128	-26	-5	355	372
LOW TEMP.	9	6	2	C	307	213	-6	12	303	272
LOW TEMP.	9	7	1	A	12	124	1	13	98	115
LOW TEMP.	9	7	2	C	280	211	0	17	181	150
LOW TEMP.	9	8	1	A	177	205	16	18	117	134
LOW TEMP.	9	8	2	C	357	218	8	14	293	262
LOW TEMP.	9	9	1	A	90	129	-29	-14	211	228
LOW TEMP.	9	9	2	C	293	212	-13	-1	388	357
LOW TEMP.	10	1	1	A	172	204	-4	11	301	318
LOW TEMP.	10	1	1	B	109	130	-15	-2	458	442
LOW TEMP.	10	1	2	C	255	209	4	10	571	540
LOW TEMP.	10	1	2	D	394	223	11	11	299	298
LOW TEMP.	10	2	1	A	157	202	-16	-3	173	190
LOW TEMP.	10	2	1	B	44	126	-24	-4	184	168
LOW TEMP.	10	2	2	C	231	208	10	20	141	110
LOW TEMP.	10	2	2	D	411	224	8	8	181	180
LOW TEMP.	10	2	2	D	375	219	9	28	184	183
LOW TEMP.	10	3	1	B	124	131	-25	-6	47	31
LOW TEMP.	10	3	2	C	328	214	-14	3	136	105
LOW TEMP.	10	4	1	B	215	207	14	20	175	159
LOW TEMP.	10	4	1	B	28	125	-9	-2	68	52
LOW TEMP.	10	4	2	C	267	210	11	15	228	197
LOW TEMP.	10	5	1	B	132	201	-19	-7	177	161
LOW TEMP.	10	5	1	B	50	127	-18	-10	152	136
LOW TEMP.	10	5	2	C	351	215	-3	3	239	208
LOW TEMP.	10	6	1	B	78	128	-26	-6	265	249
LOW TEMP.	10	6	2	C	308	213	-6	13	285	254
LOW TEMP.	10	7	1	B	196	206	-3	7	127	111
LOW TEMP.	10	7	1	B	5	124	1	13	178	162
LOW TEMP.	10	7	2	C	276	211	0	13	136	105
LOW TEMP.	10	8	1	B	188	205	16	18	206	190
LOW TEMP.	10	8	2	C	359	218	8	14	245	214
LOW TEMP.	10	9	1	B	84	129	-29	-12	309	293
LOW TEMP.	10	9	2	C	291	212	-13	-5	273	242

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW TWD	ADJ. TWD
LOW TEMP.	11	1	1	A	171	204	-4	11	126	143
LOW TEMP.	11	1	1	A	104	130	-15	-1	163	180
LOW TEMP.	11	1	2	D	401	223	11	12	211	210
LOW TEMP.	11	1	2	D	247	209	4	9	168	167
LOW TEMP.	11	2	1	A	206	206	-3	6	62	79
LOW TEMP.	11	2	1	A	156	202	-16	-5	134	151
LOW TEMP.	11	2	1	A	36	126	-24	-13	48	65
LOW TEMP.	11	2	2	D	416	224	8	12	98	97
LOW TEMP.	11	2	2	D	371	219	9	26	109	108
LOW TEMP.	11	2	2	D	240	208	10	21	53	52
LOW TEMP.	11	3	1	A	116	131	-25	-6	24	41
LOW TEMP.	11	3	2	D	333	214	-14	-2	116	115
LOW TEMP.	11	4	1	A	222	207	14	20	68	85
LOW TEMP.	11	4	1	A	20	125	-9	-2	24	41
LOW TEMP.	11	4	2	D	264	210	11	19	92	91
LOW TEMP.	11	5	1	A	139	201	-19	-10	58	75
LOW TEMP.	11	5	1	A	61	127	-18	-4	7	24
LOW TEMP.	11	5	2	D	341	215	-3	1	144	143
LOW TEMP.	11	6	1	A	70	128	-26	-6	100	117
LOW TEMP.	11	6	2	D	317	213	-6	15	176	175
LOW TEMP.	11	7	1	A	13	124	1	13	14	31
LOW TEMP.	11	7	2	D	288	211	0	17	83	82
LOW TEMP.	11	8	1	A	179	205	16	19	66	83
LOW TEMP.	11	8	2	D	365	218	8	14	119	118
LOW TEMP.	11	9	1	A	91	129	-29	-12	78	95
LOW TEMP.	11	9	2	D	301	212	-13	0	145	144
LOW TEMP.	12	1	1	B	163	204	-4	14	112	96
LOW TEMP.	12	1	1	B	110	130	-15	-2	171	155
LOW TEMP.	12	1	2	C	388	223	11	11	90	59
LOW TEMP.	12	1	2	D	246	209	4	9	98	97
LOW TEMP.	12	2	1	B	147	202	-16	-1	26	10
LOW TEMP.	12	2	1	B	43	126	-24	-13	113	97
LOW TEMP.	12	2	2	C	405	224	8	10	63	32
LOW TEMP.	12	2	2	C	381	219	9	26	69	38
LOW TEMP.	12	2	2	D	238	208	10	19	38	37
LOW TEMP.	12	3	1	B	123	131	-25	-7	40	24
LOW TEMP.	12	3	2	D	334	214	-14	0	74	73
LOW TEMP.	12	4	1	B	27	125	-9	-3	66	50
LOW TEMP.	12	4	2	D	263	210	11	18	63	62
LOW TEMP.	12	5	1	B	135	201	-19	-6	26	10
LOW TEMP.	12	5	1	B	54	127	-18	-4	35	19
LOW TEMP.	12	5	2	D	342	215	-3	2	128	127
LOW TEMP.	12	6	1	B	79	128	-26	-5	193	177
LOW TEMP.	12	6	2	D	320	213	-6	15	104	103
LOW TEMP.	12	7	1	B	6	124	1	14	104	88
LOW TEMP.	12	7	2	D	287	211	0	16	49	48
LOW TEMP.	12	8	1	B	214	207	14	20	58	42
LOW TEMP.	12	8	1	B	195	206	-3	6	100	84
LOW TEMP.	12	8	1	B	187	205	16	18	16	0
LOW TEMP.	12	8	2	D	366	218	8	14	67	66
LOW TEMP.	12	9	1	B	83	129	-29	-12	69	53
LOW TEMP.	12	9	2	D	304	212	-13	6	57	56

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IWD	ADJ. IWD
LOW TEMP.	13	1	1	A	208	206	-3	8	313	330
LOW TEMP.	13	1	1	A	175	204	-4	14	182	199
LOW TEMP.	13	1	1	A	100	130	-15	-2	208	225
LOW TEMP.	13	1	2	C	392	223	11	12	267	236
LOW TEMP.	13	1	2	C	256	209	4	9	310	279
LOW TEMP.	13	2	1	A	158	202	-16	-2	180	197
LOW TEMP.	13	2	1	A	34	126	-24	-14	201	218
LOW TEMP.	13	2	2	C	407	224	8	11	187	156
LOW TEMP.	13	2	2	C	384	219	9	28	228	197
LOW TEMP.	13	2	2	C	232	208	10	21	134	103
LOW TEMP.	13	3	1	A	224	207	14	20	92	109
LOW TEMP.	13	3	1	A	114	131	-25	-7	150	167
LOW TEMP.	13	3	2	C	324	214	-14	-2	162	131
LOW TEMP.	13	4	1	A	18	125	-9	-4	159	176
LOW TEMP.	13	4	2	C	272	210	11	19	186	155
LOW TEMP.	13	5	1	A	140	201	-19	-8	132	149
LOW TEMP.	13	5	1	A	63	127	-18	-4	106	123
LOW TEMP.	13	5	2	C	350	215	-3	2	159	128
LOW TEMP.	13	6	1	A	72	128	-26	-2	244	261
LOW TEMP.	13	6	2	C	306	213	-6	12	193	162
LOW TEMP.	13	7	1	A	10	124	1	13	137	154
LOW TEMP.	13	7	2	C	273	211	0	11	170	139
LOW TEMP.	13	8	1	A	178	205	16	18	172	189
LOW TEMP.	13	8	2	C	358	218	8	14	149	118
LOW TEMP.	13	9	1	A	93	129	-29	-11	190	207
LOW TEMP.	13	9	2	C	289	212	-13	-8	214	183
LOW TEMP.	14	1	1	B	162	204	-4	13	107	91
LOW TEMP.	14	1	1	B	111	130	-15	-2	126	110
LOW TEMP.	14	1	2	D	398	223	11	13	133	132
LOW TEMP.	14	1	2	D	248	209	4	9	142	141
LOW TEMP.	14	2	1	B	146	202	-16	-2	88	72
LOW TEMP.	14	2	1	B	42	126	-24	-14	95	79
LOW TEMP.	14	2	2	D	413	224	8	12	121	120
LOW TEMP.	14	2	2	D	374	219	9	27	46	45
LOW TEMP.	14	2	2	D	239	208	10	20	55	54
LOW TEMP.	14	3	1	B	122	131	-25	-7	49	33
LOW TEMP.	14	3	2	D	337	214	-14	5	54	53
LOW TEMP.	14	4	1	B	26	125	-9	-4	96	80
LOW TEMP.	14	4	2	D	259	210	11	15	65	64
LOW TEMP.	14	5	1	B	131	201	-19	-8	91	75
LOW TEMP.	14	5	1	B	56	127	-18	-4	58	42
LOW TEMP.	14	5	2	D	343	215	-3	2	73	72
LOW TEMP.	14	6	1	B	80	128	-26	-5	123	107
LOW TEMP.	14	6	2	D	316	213	-6	14	84	83
LOW TEMP.	14	7	1	B	194	206	-3	8	20	4
LOW TEMP.	14	7	1	B	7	124	1	14	99	83
LOW TEMP.	14	7	2	D	283	211	0	13	61	60
LOW TEMP.	14	8	1	B	216	207	14	20	35	19
LOW TEMP.	14	8	1	B	186	205	16	19	25	9
LOW TEMP.	14	8	2	D	367	218	8	14	70	69
LOW TEMP.	14	9	1	B	82	129	-29	-14	105	89
LOW TEMP.	14	9	2	D	299	212	-13	-5	97	96

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IWD	ADJ. IWD
LOW TEMP.	15	1	1	A	174	204	-4	12	343	360
LOW TEMP.	15	1	1	A	103	130	-15	-2	383	400
LOW TEMP.	15	1	2	D	396	223	11	11	353	352
LOW TEMP.	15	1	2	D	245	209	4	8	309	308
LOW TEMP.	15	2	1	A	159	202	-16	-1	104	121
LOW TEMP.	15	2	1	A	33	126	-24	-14	191	208
LOW TEMP.	15	2	2	D	412	224	8	10	142	141
LOW TEMP.	15	2	2	D	376	219	9	28	112	111
LOW TEMP.	15	2	2	D	237	208	10	18	150	149
LOW TEMP.	15	3	1	A	115	131	-25	-7	68	85
LOW TEMP.	15	3	2	D	335	214	-14	4	78	77
LOW TEMP.	15	4	1	A	221	207	14	20	155	172
LOW TEMP.	15	4	1	A	17	125	-9	-4	128	145
LOW TEMP.	15	4	2	D	262	210	11	18	199	198
LOW TEMP.	15	5	1	A	143	201	-19	-6	310	327
LOW TEMP.	15	5	1	A	64	127	-18	-3	217	234
LOW TEMP.	15	5	2	D	344	215	-3	3	291	290
LOW TEMP.	15	6	1	A	66	128	-26	-6	416	433
LOW TEMP.	15	6	2	D	319	213	-6	15	274	273
LOW TEMP.	15	7	1	A	9	124	1	13	61	78
LOW TEMP.	15	7	2	D	286	211	0	16	99	98
LOW TEMP.	15	8	1	A	180	205	16	20	218	235
LOW TEMP.	15	8	2	D	368	218	8	16	268	267
LOW TEMP.	15	9	1	A	205	206	-3	4	277	294
LOW TEMP.	15	9	1	A	96	129	-29	-8	257	274
LOW TEMP.	15	9	2	D	303	212	-13	4	344	343
LOW TEMP.	16	1	1	B	193	206	-3	4	44	28
LOW TEMP.	16	1	1	B	167	204	-4	11	93	77
LOW TEMP.	16	1	1	B	112	130	-15	-1	33	17
LOW TEMP.	16	1	2	C	390	223	11	13	23	-8
LOW TEMP.	16	1	2	C	251	209	4	8	21	-10
LOW TEMP.	16	2	1	B	145	202	-16	-13	6	-10
LOW TEMP.	16	2	1	B	41	126	-24	-14	49	33
LOW TEMP.	16	2	2	C	404	224	8	10	25	-6
LOW TEMP.	16	2	2	C	378	219	9	26	2	-29
LOW TEMP.	16	2	2	C	227	208	10	15	6	-25
LOW TEMP.	16	3	1	B	121	131	-25	-7	2	-14
LOW TEMP.	16	3	2	C	325	214	-14	-2	24	-7
LOW TEMP.	16	4	1	B	25	125	-9	-4	7	-9
LOW TEMP.	16	4	2	C	265	210	11	14	18	-13
LOW TEMP.	16	5	1	B	129	201	-19	-12	13	-3
LOW TEMP.	16	5	1	B	55	127	-18	-4	76	60
LOW TEMP.	16	5	2	C	346	215	-3	-2	18	-13
LOW TEMP.	16	6	1	B	74	128	-26	-9	69	53
LOW TEMP.	16	6	2	C	309	213	-6	15	67	36
LOW TEMP.	16	7	1	B	8	124	1	14	50	34
LOW TEMP.	16	7	2	C	274	211	0	11	7	-24
LOW TEMP.	16	8	1	B	212	207	14	20	30	14
LOW TEMP.	16	8	1	B	185	205	16	20	0	-16
LOW TEMP.	16	8	2	C	354	218	8	12	15	-16
LOW TEMP.	16	9	1	B	81	129	-29	-15	3	-13
LOW TEMP.	16	9	2	C	292	212	-13	-2	24	-7

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IWD	ADJ. IWD
INTERMEDIATE	1	1	1	E	527	416	27	48	255	235
INTERMEDIATE	1	1	1	G	647	425	44	54	188	204
INTERMEDIATE	1	1	2	H	899	514	37	51	250	284
INTERMEDIATE	1	1	2	I	860	512	32	50	163	162
INTERMEDIATE	1	2	1	E	501	415	34	45	96	76
INTERMEDIATE	1	2	1	G	666	426	42	57	62	78
INTERMEDIATE	1	2	2	H	818	507	33	43	89	123
INTERMEDIATE	1	2	2	I	738	501	42	58	103	102
INTERMEDIATE	1	3	1	G	604	422	60	69	41	57
INTERMEDIATE	1	3	1	G	699	429	38	54	54	70
INTERMEDIATE	1	3	2	I	761	503	44	56	64	63
INTERMEDIATE	1	4	1	G	644	424	32	50	94	110
INTERMEDIATE	1	4	2	I	848	509	30	48	166	165
INTERMEDIATE	1	5	1	G	620	423	38	47	40	56
INTERMEDIATE	1	5	2	I	877	513	42	48	65	64
INTERMEDIATE	1	6	1	E	567	419	50	52	148	128
INTERMEDIATE	1	6	2	I	835	508	38	46	143	142
INTERMEDIATE	1	7	1	E	592	421	46	55	92	72
INTERMEDIATE	1	7	1	G	716	430	40	61	94	110
INTERMEDIATE	1	7	2	I	786	505	58	59	81	80
INTERMEDIATE	1	8	1	E	551	418	36	50	148	128
INTERMEDIATE	1	8	2	I	747	502	44	58	127	126
INTERMEDIATE	1	9	1	E	534	417	44	53	184	164
INTERMEDIATE	1	9	1	G	683	428	34	52	152	168
INTERMEDIATE	1	9	2	I	794	506	39	48	101	100
INTERMEDIATE	2	1	1	D	523	416	27	54	182	181
INTERMEDIATE	2	1	1	D	653	425	44	52	195	194
INTERMEDIATE	2	1	2	H	869	512	32	51	146	180
INTERMEDIATE	2	1	2	I	894	514	37	53	184	183
INTERMEDIATE	2	2	1	D	510	415	34	46	67	66
INTERMEDIATE	2	2	1	D	670	426	42	52	117	116
INTERMEDIATE	2	2	2	H	731	501	42	59	112	146
INTERMEDIATE	2	2	2	I	811	507	33	42	118	117
INTERMEDIATE	2	3	1	D	610	422	60	66	61	60
INTERMEDIATE	2	3	1	D	703	429	38	47	60	59
INTERMEDIATE	2	3	2	H	770	503	44	60	54	88
INTERMEDIATE	2	4	1	D	629	424	32	40	185	184
INTERMEDIATE	2	4	2	H	841	509	30	50	145	179
INTERMEDIATE	2	5	1	D	626	423	38	45	87	86
INTERMEDIATE	2	5	2	H	885	513	42	48	70	104
INTERMEDIATE	2	6	1	D	577	419	50	55	117	116
INTERMEDIATE	2	6	2	H	825	508	38	45	168	202
INTERMEDIATE	2	7	1	D	588	421	46	62	78	77
INTERMEDIATE	2	7	1	D	720	430	40	54	73	72
INTERMEDIATE	2	7	2	H	780	505	58	60	50	84
INTERMEDIATE	2	7	2	H	853	510	31	53	72	106
INTERMEDIATE	2	8	1	D	562	418	36	56	113	112
INTERMEDIATE	2	8	2	H	755	502	44	58	126	160
INTERMEDIATE	2	9	1	D	546	417	44	58	72	71
INTERMEDIATE	2	9	1	D	687	428	34	48	163	162
INTERMEDIATE	2	9	2	H	804	506	39	48	108	142
INTERMEDIATE	3	1	1	D	524	416	27	55	188	137

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW TWD	ADJ. TWD
INTERMEDIATE	3	1	1	G	645	425	44	52	208	224
INTERMEDIATE	3	1	2	I	859	512	32	49	195	194
INTERMEDIATE	3	1	2	I	888	514	37	48	217	216
INTERMEDIATE	3	2	1	D	509	415	34	46	16	15
INTERMEDIATE	3	2	1	G	663	426	42	53	81	97
INTERMEDIATE	3	2	2	I	739	501	42	59	97	96
INTERMEDIATE	3	2	2	I	808	507	33	41	40	39
INTERMEDIATE	3	3	1	D	606	422	60	61	53	52
INTERMEDIATE	3	3	1	D	705	429	38	50	20	19
INTERMEDIATE	3	3	2	I	758	503	44	50	48	47
INTERMEDIATE	3	4	1	D	630	424	32	42	158	157
INTERMEDIATE	3	4	2	I	850	509	30	52	174	173
INTERMEDIATE	3	5	1	D	622	423	38	41	49	48
INTERMEDIATE	3	5	2	I	878	513	42	50	15	14
INTERMEDIATE	3	6	1	D	575	419	50	52	198	197
INTERMEDIATE	3	6	2	I	833	508	38	45	121	120
INTERMEDIATE	3	7	1	D	581	421	46	51	69	68
INTERMEDIATE	3	7	1	D	722	430	40	58	34	33
INTERMEDIATE	3	7	2	I	783	505	58	60	58	57
INTERMEDIATE	3	8	1	D	559	418	36	50	94	93
INTERMEDIATE	3	8	2	I	746	502	44	57	85	84
INTERMEDIATE	3	9	1	D	548	417	44	61	83	82
INTERMEDIATE	3	9	1	D	689	428	34	50	160	159
INTERMEDIATE	3	9	2	I	791	506	39	46	58	57
INTERMEDIATE	4	1	1	E	529	416	27	52	149	129
INTERMEDIATE	4	1	1	G	650	425	44	57	165	181
INTERMEDIATE	4	1	2	H	866	512	32	48	120	154
INTERMEDIATE	4	1	2	H	901	514	37	53	145	179
INTERMEDIATE	4	2	1	E	507	415	34	41	53	33
INTERMEDIATE	4	2	1	G	664	426	42	55	58	74
INTERMEDIATE	4	2	2	H	732	501	42	61	48	82
INTERMEDIATE	4	2	2	H	816	507	33	40	47	81
INTERMEDIATE	4	3	1	G	599	422	60	61	36	52
INTERMEDIATE	4	3	1	G	697	429	38	50	32	48
INTERMEDIATE	4	3	2	H	768	503	44	53	25	59
INTERMEDIATE	4	4	1	G	640	424	32	45	132	148
INTERMEDIATE	4	4	2	H	840	509	30	48	96	130
INTERMEDIATE	4	5	1	G	615	423	38	42	42	58
INTERMEDIATE	4	5	2	H	884	513	42	48	39	73
INTERMEDIATE	4	6	1	E	570	419	50	56	108	88
INTERMEDIATE	4	6	2	H	823	508	38	43	105	139
INTERMEDIATE	4	7	1	E	589	421	46	51	116	96
INTERMEDIATE	4	7	1	G	715	430	40	59	52	68
INTERMEDIATE	4	7	2	H	777	505	58	59	35	69
INTERMEDIATE	4	8	1	E	549	418	36	45	111	91
INTERMEDIATE	4	8	2	H	756	502	44	60	37	71
INTERMEDIATE	4	9	1	E	540	417	44	60	79	59
INTERMEDIATE	4	9	1	G	681	428	34	50	115	131
INTERMEDIATE	4	9	2	H	801	506	39	47	45	79
INTERMEDIATE	5	1	1	D	660	425	44	56	121	120
INTERMEDIATE	5	1	1	E	531	416	27	54	129	109
INTERMEDIATE	5	1	2	I	861	512	32	51	122	121

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IWD	ADJ. IWD
INTERMEDIATE	5	1	2	I	890	514	37	50	120	119
INTERMEDIATE	5	2	1	D	676	426	42	57	96	95
INTERMEDIATE	5	2	1	E	503	415	34	44	13	-7
INTERMEDIATE	5	2	2	I	736	501	42	56	64	63
INTERMEDIATE	5	2	2	I	807	507	33	40	30	29
INTERMEDIATE	5	3	1	G	603	422	60	68	50	66
INTERMEDIATE	5	3	1	G	700	429	38	54	34	50
INTERMEDIATE	5	3	2	I	757	503	44	49	24	23
INTERMEDIATE	5	4	1	G	643	424	32	49	89	96
INTERMEDIATE	5	4	2	I	851	509	30	53	59	58
INTERMEDIATE	5	5	1	G	619	423	38	45	44	60
INTERMEDIATE	5	5	2	I	871	513	42	47	57	56
INTERMEDIATE	5	6	1	E	572	419	50	59	75	55
INTERMEDIATE	5	6	2	I	832	508	38	45	54	53
INTERMEDIATE	5	7	1	E	593	421	46	57	64	44
INTERMEDIATE	5	7	1	G	714	430	40	58	42	58
INTERMEDIATE	5	7	2	I	781	505	58	60	18	17
INTERMEDIATE	5	8	1	E	556	418	36	61	49	29
INTERMEDIATE	5	8	2	I	741	502	44	48	76	75
INTERMEDIATE	5	9	1	E	538	417	44	58	90	70
INTERMEDIATE	5	9	1	G	684	428	34	54	66	82
INTERMEDIATE	5	9	2	I	789	506	39	45	52	51
INTERMEDIATE	6	1	1	D	521	416	27	52	286	285
INTERMEDIATE	6	1	1	G	651	425	44	58	232	248
INTERMEDIATE	6	1	2	H	867	512	32	49	276	310
INTERMEDIATE	6	1	2	I	891	514	37	51	550	549
INTERMEDIATE	6	2	1	D	513	415	34	44	150	149
INTERMEDIATE	6	2	1	G	668	426	42	58	224	240
INTERMEDIATE	6	2	2	H	729	501	42	58	74	108
INTERMEDIATE	6	2	2	I	809	507	33	41	277	276
INTERMEDIATE	6	3	1	D	608	422	60	61	185	184
INTERMEDIATE	6	3	1	D	702	429	38	47	160	159
INTERMEDIATE	6	3	2	H	765	503	44	49	79	113
INTERMEDIATE	6	4	1	D	633	424	32	46	270	269
INTERMEDIATE	6	4	2	H	842	509	30	52	248	282
INTERMEDIATE	6	5	1	D	624	423	38	42	175	174
INTERMEDIATE	6	5	2	H	879	513	42	47	119	153
INTERMEDIATE	6	6	1	D	579	419	50	58	240	239
INTERMEDIATE	6	6	2	H	824	508	38	45	234	268
INTERMEDIATE	6	7	1	D	583	421	46	53	219	218
INTERMEDIATE	6	7	1	D	719	430	40	53	192	191
INTERMEDIATE	6	7	2	H	773	505	58	60	105	139
INTERMEDIATE	6	8	1	D	564	418	36	62	175	174
INTERMEDIATE	6	8	2	H	753	502	44	55	121	155
INTERMEDIATE	6	9	1	D	545	417	44	55	212	211
INTERMEDIATE	6	9	1	D	686	428	34	46	324	323
INTERMEDIATE	6	9	2	H	799	506	39	46	222	256
INTERMEDIATE	7	1	1	D	520	416	27	50	357	356
INTERMEDIATE	7	1	1	G	649	425	44	56	427	443
INTERMEDIATE	7	1	2	H	897	514	37	50	260	294
INTERMEDIATE	7	1	2	I	857	512	32	47	293	292
INTERMEDIATE	7	2	1	D	511	415	34	42	201	200

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW TWD	ADJ. TWD
INTERMEDIATE	7	2	1	G	667	426	42	56	153	169
INTERMEDIATE	7	2	2	H	817	507	33	41	178	212
INTERMEDIATE	7	2	2	I	740	501	42	61	307	306
INTERMEDIATE	7	3	1	D	607	422	60	61	238	237
INTERMEDIATE	7	3	1	D	708	429	38	54	192	191
INTERMEDIATE	7	3	2	I	760	503	44	53	175	174
INTERMEDIATE	7	4	1	D	632	424	32	45	346	345
INTERMEDIATE	7	4	2	I	845	509	30	44	296	295
INTERMEDIATE	7	5	1	D	623	423	38	42	281	280
INTERMEDIATE	7	5	2	I	874	513	42	48	206	205
INTERMEDIATE	7	6	1	D	580	419	50	60	341	340
INTERMEDIATE	7	6	2	I	829	508	38	42	342	341
INTERMEDIATE	7	7	1	D	587	421	46	60	349	348
INTERMEDIATE	7	7	1	D	724	430	40	61	216	215
INTERMEDIATE	7	7	2	I	785	505	58	59	178	177
INTERMEDIATE	7	8	1	D	563	418	36	59	236	235
INTERMEDIATE	7	8	2	I	748	502	44	60	235	234
INTERMEDIATE	7	9	1	D	544	417	44	54	272	271
INTERMEDIATE	7	9	1	D	692	428	34	54	309	308
INTERMEDIATE	7	9	2	I	793	506	39	47	196	195
INTERMEDIATE	8	1	1	D	655	425	44	54	168	167
INTERMEDIATE	8	1	1	E	528	416	27	50	134	114
INTERMEDIATE	8	1	2	H	870	512	32	53	122	156
INTERMEDIATE	8	1	2	I	893	514	37	53	185	184
INTERMEDIATE	8	2	1	D	672	426	42	55	156	155
INTERMEDIATE	8	2	1	E	508	415	34	40	67	47
INTERMEDIATE	8	2	2	H	730	501	42	58	63	97
INTERMEDIATE	8	2	2	I	810	507	33	43	124	123
INTERMEDIATE	8	3	1	G	600	422	60	62	176	192
INTERMEDIATE	8	3	1	G	696	429	38	49	114	130
INTERMEDIATE	8	3	2	H	766	503	44	50	71	105
INTERMEDIATE	8	4	1	G	637	424	32	40	106	122
INTERMEDIATE	8	4	2	H	843	509	30	53	68	102
INTERMEDIATE	8	5	1	G	616	423	38	42	110	126
INTERMEDIATE	8	5	2	H	882	513	42	48	57	91
INTERMEDIATE	8	6	1	E	569	419	50	55	186	166
INTERMEDIATE	8	6	2	H	826	508	38	46	74	108
INTERMEDIATE	8	7	1	E	596	421	46	62	171	151
INTERMEDIATE	8	7	1	G	712	430	40	54	71	87
INTERMEDIATE	8	7	2	H	775	504	58	60	65	99
INTERMEDIATE	8	8	1	E	554	418	36	56	109	89
INTERMEDIATE	8	8	2	H	754	502	44	57	71	105
INTERMEDIATE	8	9	1	E	536	417	44	54	148	128
INTERMEDIATE	8	9	1	G	680	428	34	49	99	115
INTERMEDIATE	8	9	2	H	800	506	39	47	72	106
INTERMEDIATE	9	1	1	D	669	426	42	51	227	226
INTERMEDIATE	9	1	1	E	535	417	44	54	256	236
INTERMEDIATE	9	1	2	H	815	507	33	40	257	291
INTERMEDIATE	9	1	2	I	763	503	44	62	168	167
INTERMEDIATE	9	2	1	D	657	425	44	56	102	101
INTERMEDIATE	9	2	1	E	525	416	27	46	152	132
INTERMEDIATE	9	2	2	H	902	514	37	53	116	150

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	IWD	ADJ. IWD
INTERMEDIATE	9	2	2	I	858	512	32	47	145	144
INTERMEDIATE	9	3	1	E	552	418	36	52	100	80
INTERMEDIATE	9	3	2	I	834	508	38	46	28	27
INTERMEDIATE	9	4	1	E	505	415	34	42	150	130
INTERMEDIATE	9	4	1	G	678	428	34	46	172	188
INTERMEDIATE	9	4	2	I	734	501	42	50	134	133
INTERMEDIATE	9	5	1	G	601	422	60	64	82	98
INTERMEDIATE	9	5	1	G	694	429	38	47	97	113
INTERMEDIATE	9	5	2	I	849	509	30	50	67	66
INTERMEDIATE	9	6	1	E	595	421	46	60	197	177
INTERMEDIATE	9	6	1	G	710	430	40	52	136	202
INTERMEDIATE	9	6	2	I	788	505	58	60	177	176
INTERMEDIATE	9	7	1	G	617	423	38	44	104	120
INTERMEDIATE	9	7	2	I	876	513	42	48	79	78
INTERMEDIATE	9	8	1	G	641	424	32	46	176	192
INTERMEDIATE	9	8	2	I	796	506	39	48	133	132
INTERMEDIATE	9	9	1	E	568	419	50	54	170	150
INTERMEDIATE	9	9	2	I	743	502	44	50	155	154
INTERMEDIATE	10	1	1	D	674	426	42	57	203	202
INTERMEDIATE	10	1	1	E	533	417	44	50	172	152
INTERMEDIATE	10	1	2	H	767	503	44	52	158	192
INTERMEDIATE	10	1	2	H	814	507	33	40	151	185
INTERMEDIATE	10	2	1	D	659	425	44	58	128	127
INTERMEDIATE	10	2	1	E	526	416	27	48	138	118
INTERMEDIATE	10	2	2	H	865	512	32	47	114	148
INTERMEDIATE	10	2	2	H	896	514	37	48	114	148
INTERMEDIATE	10	3	1	E	550	418	36	46	91	71
INTERMEDIATE	10	3	2	H	822	508	38	43	55	89
INTERMEDIATE	10	4	1	E	504	415	34	43	172	152
INTERMEDIATE	10	4	1	G	679	428	34	48	184	200
INTERMEDIATE	10	4	2	H	728	501	42	56	158	192
INTERMEDIATE	10	5	1	G	602	422	60	65	69	85
INTERMEDIATE	10	5	1	G	695	429	38	48	98	114
INTERMEDIATE	10	5	2	H	839	509	30	47	48	82
INTERMEDIATE	10	6	1	E	591	421	46	53	183	163
INTERMEDIATE	10	6	1	G	711	430	40	53	191	207
INTERMEDIATE	10	6	2	H	774	505	58	60	135	169
INTERMEDIATE	10	7	1	G	618	423	38	45	90	106
INTERMEDIATE	10	7	2	H	883	513	42	48	104	138
INTERMEDIATE	10	8	1	G	642	424	32	48	185	201
INTERMEDIATE	10	8	2	H	798	506	39	45	103	137
INTERMEDIATE	10	9	1	E	566	419	50	51	157	137
INTERMEDIATE	10	9	2	H	749	502	44	48	146	180
INTERMEDIATE	11	1	1	D	542	417	44	52	116	115
INTERMEDIATE	11	1	1	D	673	426	42	55	137	136
INTERMEDIATE	11	1	2	I	759	503	44	52	123	122
INTERMEDIATE	11	1	2	I	806	507	33	40	190	189
INTERMEDIATE	11	2	1	D	518	416	27	48	83	82
INTERMEDIATE	11	2	1	D	656	425	44	55	75	74
INTERMEDIATE	11	2	2	I	855	512	32	45	96	95
INTERMEDIATE	11	2	2	I	887	514	37	46	70	69
INTERMEDIATE	11	3	1	D	557	418	36	45	54	53

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IWD	ADJ. IWD
INTERMEDIATE	11	3	2	I	831	508	38	43	78	77
INTERMEDIATE	11	4	1	D	516	415	34	40	82	81
INTERMEDIATE	11	4	1	D	690	428	34	52	142	141
INTERMEDIATE	11	4	2	I	735	501	42	53	163	162
INTERMEDIATE	11	5	1	D	605	422	60	61	74	73
INTERMEDIATE	11	5	1	D	706	429	38	51	71	70
INTERMEDIATE	11	5	2	I	846	509	30	44	69	68
INTERMEDIATE	11	6	1	D	582	421	46	53	126	125
INTERMEDIATE	11	6	1	D	718	430	40	52	98	97
INTERMEDIATE	11	6	2	I	782	505	58	60	85	84
INTERMEDIATE	11	7	1	D	621	423	38	40	131	130
INTERMEDIATE	11	7	2	I	872	513	42	47	78	77
INTERMEDIATE	11	8	1	D	631	424	32	44	87	86
INTERMEDIATE	11	8	2	I	790	506	39	45	107	106
INTERMEDIATE	11	9	1	D	573	419	50	50	119	118
INTERMEDIATE	11	9	2	I	744	502	44	52	98	97
INTERMEDIATE	12	1	1	D	541	417	44	50	101	100
INTERMEDIATE	12	1	1	G	661	426	42	51	126	142
INTERMEDIATE	12	1	2	H	771	503	44	62	112	146
INTERMEDIATE	12	1	2	H	819	507	33	42	117	151
INTERMEDIATE	12	2	1	D	517	416	27	46	74	73
INTERMEDIATE	12	2	1	G	652	425	44	56	52	68
INTERMEDIATE	12	2	2	H	864	512	32	46	49	83
INTERMEDIATE	12	2	2	H	898	514	37	50	80	114
INTERMEDIATE	12	3	1	D	558	418	36	46	52	51
INTERMEDIATE	12	3	2	H	828	508	38	43	62	96
INTERMEDIATE	12	4	1	D	515	415	34	41	51	50
INTERMEDIATE	12	4	1	D	685	428	34	45	129	128
INTERMEDIATE	12	4	2	H	727	501	42	53	174	208
INTERMEDIATE	12	5	1	D	609	422	60	64	79	78
INTERMEDIATE	12	5	1	D	701	429	38	46	86	85
INTERMEDIATE	12	5	2	H	838	509	30	44	68	102
INTERMEDIATE	12	6	1	D	584	421	46	55	125	124
INTERMEDIATE	12	6	1	D	717	430	40	50	100	99
INTERMEDIATE	12	6	2	H	779	505	58	60	83	117
INTERMEDIATE	12	7	1	D	625	423	38	44	78	77
INTERMEDIATE	12	7	2	H	880	513	42	47	48	82
INTERMEDIATE	12	8	1	D	635	424	32	49	94	93
INTERMEDIATE	12	8	2	H	803	506	39	48	82	116
INTERMEDIATE	12	9	1	D	574	419	50	51	62	61
INTERMEDIATE	12	9	2	H	752	502	44	52	103	137
INTERMEDIATE	13	1	1	E	537	417	44	55	305	285
INTERMEDIATE	13	1	1	G	665	426	42	56	110	126
INTERMEDIATE	13	1	2	H	820	507	33	44	130	164
INTERMEDIATE	13	1	2	I	762	503	44	60	258	257
INTERMEDIATE	13	2	1	E	530	416	27	53	163	143
INTERMEDIATE	13	2	1	G	646	425	44	54	59	75
INTERMEDIATE	13	2	2	H	895	514	37	46	66	100
INTERMEDIATE	13	2	2	I	862	512	32	53	122	121
INTERMEDIATE	13	3	1	E	555	418	36	59	96	76
INTERMEDIATE	13	3	2	I	836	508	38	46	147	146
INTERMEDIATE	13	4	1	E	506	415	34	41	131	111

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IWD	ADJ. IWD
INTERMEDIATE	13	4	1	G	682	428	34	52	103	119
INTERMEDIATE	13	4	2	I	733	501	42	49	243	242
INTERMEDIATE	13	5	1	G	597	422	60	61	62	73
INTERMEDIATE	13	5	1	G	698	429	38	50	66	82
INTERMEDIATE	13	5	2	I	852	509	30	55	50	49
INTERMEDIATE	13	6	1	E	594	421	46	53	294	274
INTERMEDIATE	13	6	1	G	713	430	40	56	199	215
INTERMEDIATE	13	6	2	I	787	505	58	60	171	170
INTERMEDIATE	13	7	1	G	613	423	38	40	89	105
INTERMEDIATE	13	7	2	I	873	513	42	47	159	158
INTERMEDIATE	13	8	1	G	638	424	32	42	118	134
INTERMEDIATE	13	8	2	I	795	506	39	48	170	169
INTERMEDIATE	13	9	1	E	571	419	50	58	230	210
INTERMEDIATE	13	9	2	I	742	502	44	48	206	205
INTERMEDIATE	14	1	1	D	543	417	44	54	81	80
INTERMEDIATE	14	1	1	D	671	426	42	53	114	113
INTERMEDIATE	14	1	2	H	769	503	44	56	79	113
INTERMEDIATE	14	1	2	I	812	507	33	44	147	146
INTERMEDIATE	14	2	1	D	519	416	27	48	45	44
INTERMEDIATE	14	2	1	D	654	425	44	54	66	65
INTERMEDIATE	14	2	2	H	868	512	32	50	32	66
INTERMEDIATE	14	2	2	I	889	514	37	50	102	101
INTERMEDIATE	14	3	1	D	561	418	36	54	52	51
INTERMEDIATE	14	3	2	H	827	508	38	46	23	57
INTERMEDIATE	14	4	1	D	514	415	34	41	48	47
INTERMEDIATE	14	4	1	D	688	428	34	49	83	82
INTERMEDIATE	14	4	2	H	725	501	42	49	95	129
INTERMEDIATE	14	5	1	D	612	422	60	69	79	78
INTERMEDIATE	14	5	1	D	704	429	38	48	52	51
INTERMEDIATE	14	5	2	H	844	509	30	55	27	61
INTERMEDIATE	14	6	1	D	586	421	46	58	143	142
INTERMEDIATE	14	6	1	D	721	430	40	56	40	39
INTERMEDIATE	14	6	2	H	778	505	58	59	58	92
INTERMEDIATE	14	7	1	D	628	423	38	46	70	69
INTERMEDIATE	14	7	2	H	886	513	42	50	42	76
INTERMEDIATE	14	8	1	D	636	424	32	50	59	58
INTERMEDIATE	14	8	2	H	802	506	39	48	27	61
INTERMEDIATE	14	9	1	D	578	419	50	56	73	72
INTERMEDIATE	14	9	2	H	750	502	44	48	76	110
INTERMEDIATE	15	1	1	D	547	417	44	59	196	195
INTERMEDIATE	15	1	1	D	675	426	42	57	273	272
INTERMEDIATE	15	1	2	I	764	503	44	64	61	60
INTERMEDIATE	15	1	2	I	805	507	33	40	221	220
INTERMEDIATE	15	1	2	I	854	510	31	53	290	289
INTERMEDIATE	15	2	1	D	522	416	27	52	82	81
INTERMEDIATE	15	2	1	D	658	425	44	57	91	90
INTERMEDIATE	15	2	2	I	856	512	32	46	120	119
INTERMEDIATE	15	2	2	I	892	514	37	52	153	152
INTERMEDIATE	15	3	1	D	560	418	36	52	44	43
INTERMEDIATE	15	3	2	I	830	508	38	42	25	24
INTERMEDIATE	15	4	1	D	512	415	34	44	150	149
INTERMEDIATE	15	4	1	D	691	428	34	52	187	186

(Continued)

TABLE C-1. LISTING OF TEST RESULTS

TEST PHASE	CAR NO.	FUEL NO.	BLOCK	RATER	RUN NO.	DATE	SOAK TEMP., °F	RUN TEMP., °F	RAW IWD	ADJ. IWD
INTERMEDIATE	15	4	2	I	737	501	42	58	106	105
INTERMEDIATE	15	5	1	D	611	422	60	68	74	73
INTERMEDIATE	15	5	1	D	707	429	38	52	107	106
INTERMEDIATE	15	5	2	I	847	509	30	47	114	113
INTERMEDIATE	15	6	1	D	585	421	46	57	144	143
INTERMEDIATE	15	6	1	D	723	430	40	59	188	187
INTERMEDIATE	15	6	2	I	784	505	58	59	101	100
INTERMEDIATE	15	7	1	D	627	423	38	46	79	78
INTERMEDIATE	15	7	2	I	875	513	42	48	133	132
INTERMEDIATE	15	8	1	D	634	424	32	48	153	152
INTERMEDIATE	15	8	2	I	792	506	39	47	127	126
INTERMEDIATE	15	9	1	D	576	419	50	54	126	125
INTERMEDIATE	15	9	2	I	745	502	44	55	93	92
INTERMEDIATE	16	1	1	E	539	417	44	59	103	83
INTERMEDIATE	16	1	1	G	662	426	42	52	70	86
INTERMEDIATE	16	1	2	H	772	503	44	64	44	78
INTERMEDIATE	16	1	2	H	813	507	33	40	30	64
INTERMEDIATE	16	2	1	E	532	416	27	55	12	-8
INTERMEDIATE	16	2	1	G	648	425	44	55	24	40
INTERMEDIATE	16	2	2	H	863	512	32	45	9	43
INTERMEDIATE	16	2	2	H	900	514	37	52	15	49
INTERMEDIATE	16	3	1	E	553	418	36	54	16	-4
INTERMEDIATE	16	3	2	H	821	508	38	42	26	60
INTERMEDIATE	16	4	1	E	502	415	34	45	98	78
INTERMEDIATE	16	4	1	G	677	428	34	45	46	62
INTERMEDIATE	16	4	2	H	726	501	42	50	38	72
INTERMEDIATE	16	5	1	G	598	422	60	61	26	42
INTERMEDIATE	16	5	1	G	693	429	38	46	8	24
INTERMEDIATE	16	5	2	H	837	509	30	44	15	49
INTERMEDIATE	16	6	1	E	590	421	46	52	54	34
INTERMEDIATE	16	6	1	G	709	430	40	50	64	80
INTERMEDIATE	16	6	2	H	776	505	58	59	32	66
INTERMEDIATE	16	7	1	G	614	423	38	41	86	102
INTERMEDIATE	16	7	2	H	881	513	42	47	29	63
INTERMEDIATE	16	8	1	G	639	424	32	44	54	70
INTERMEDIATE	16	8	2	H	797	506	39	45	36	70
INTERMEDIATE	16	9	1	E	565	419	50	50	42	[illegible]
INTERMEDIATE	16	9	2	H	751	502	44	50	20	54

AD-A119 146 COORDINATING RESEARCH COUNCIL INC ATLANTA GA F/G 21/4
EFFECTS OF FUEL VOLATILITY ON DRIVEABILITY OF 1980 MODEL CARS A--ETC(U)
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UNCLASSIFIED CRC-524 NL

2 of 2

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TABLE C-2. RAW TOTAL WEIGHTED DEMERITS SUMMARY

LOW TEMPERATURE PHASE

CAR	FUEL 1	FUEL 2	FUEL 3	FUEL 4	FUEL 5	FUEL 6	FUEL 7	FUEL 8	FUEL 9	MEAN
1	222.3	131.8	92.5	174.0	148.3	155.8	118.0	163.8	139.5	149.5
2	222.5	175.0	160.8	192.3	149.0	307.0	111.0	225.0	163.5	189.6
3	257.6	66.0	18.0	114.0	100.5	134.5	54.8	108.5	183.5	115.3
4	144.5	77.8	26.5	103.5	77.0	185.5	33.5	124.8	56.5	92.2
5	117.8	40.8	33.5	57.5	49.0	107.5	33.3	86.5	58.0	64.9
6	213.0	86.5	56.5	105.5	161.5	248.3	76.0	164.5	104.0	135.1
7	429.8	306.0	223.8	290.0	285.5	305.5	247.3	322.0	234.0	293.8
8	88.7	43.0	52.0	71.5	61.5	120.0	42.0	76.0	71.5	69.6
9	294.0	180.1	141.0	181.5	253.3	329.0	139.5	205.0	299.5	224.8
10	407.3	173.6	91.5	174.8	201.8	275.0	144.3	225.5	291.0	220.5
11	167.0	84.0	70.0	69.0	88.3	138.0	48.5	92.5	111.5	96.5
12	117.8	63.1	57.0	64.5	79.3	148.5	76.5	62.5	63.0	81.3
13	261.4	186.8	141.5	172.5	139.0	218.5	153.5	160.5	202.0	181.7
14	127.0	82.8	51.5	80.5	73.8	103.5	60.3	50.0	101.0	81.1
15	347.0	141.1	73.0	170.3	277.3	345.0	80.0	243.0	305.5	220.2
16	39.3	19.3	13.0	12.5	31.3	68.0	28.5	15.0	13.5	26.7
MEAN	216.1	116.1	81.4	127.1	136.0	199.3	90.4	145.3	149.8	140.2

INTERMEDIATE TEMPERATURE PHASE

CAR	FUEL 1	FUEL 2	FUEL 3	FUEL 4	FUEL 5	FUEL 6	FUEL 7	FUEL 8	FUEL 9	MEAN
1	214.0	87.5	55.8	130.0	52.5	145.5	87.0	137.5	134.5	116.0
2	176.8	103.5	57.3	165.0	78.5	142.5	68.3	119.5	112.8	113.8
3	202.0	58.5	42.3	166.0	32.0	159.5	54.8	89.5	89.8	99.4
4	144.8	51.5	29.5	114.0	40.5	106.5	59.5	74.0	71.0	76.8
5	123.0	50.8	33.0	69.5	50.5	64.5	35.5	62.5	65.0	61.6
6	336.0	181.3	125.8	259.0	147.0	237.0	155.3	148.0	245.0	203.8
7	334.3	209.8	195.0	321.0	243.5	341.5	230.3	235.5	243.3	261.6
8	152.3	102.5	108.0	87.0	83.5	130.0	93.0	90.0	97.8	104.9
9	227.0	128.8	64.0	147.5	78.3	134.3	91.5	154.5	162.5	137.6
10	171.0	123.5	73.0	168.0	65.8	161.0	97.0	144.0	151.5	128.3
11	141.5	81.0	66.0	137.5	70.8	98.5	104.5	97.0	108.5	100.6
12	114.0	63.8	57.0	132.0	75.3	97.8	63.0	88.0	82.5	85.9
13	200.8	102.5	121.5	180.0	57.0	208.8	124.0	144.0	218.0	150.7
14	105.3	61.3	37.5	80.3	46.3	74.8	56.0	43.0	74.5	64.3
15	212.6	111.5	34.5	137.3	102.3	133.5	106.0	140.0	109.5	120.8
16	61.8	15.0	21.0	55.0	16.0	45.5	57.5	45.0	31.0	38.6
MEAN	182.3	95.8	70.1	146.8	77.5	145.7	92.7	113.3	124.8	116.5

A P P E N D I X   D

DEVELOPMENT OF RATER CORRECTION FACTORS AND PRECISION STATEMENTS

DEVELOPMENT OF RATER CORRECTION FACTORS AND PRECISION STATEMENTS

STEP 1: Determine offsets between raters on-site simultaneously.

To determine these individual rater offsets, the data for each phase were broken into four segments based on test cars and test days. In both phases, cars 1-8 were grouped and cars 9-16 were grouped, because all cars in each group followed the same fueling schedule. The data for the low temperature phase were also divided by grouping days 1-11 and days 15-26, because Raters A and B were on-site in the first portion, and Raters C and D were on-site in the latter days. Days 12, 13, and 14 were eliminated to avoid trying to identify day-by-fuel interactions on these days which would not occur on other days. The data for the intermediate temperature phase were divided at day 14, when the rater teams changed. The following eight linear regressions were run to determine the individual rater offsets:

DATA	EQUATION FORM*	EQUATION NUMBER

LOW TEMPERATURE PHASE

Days 1-11

Cars 1-8

$$\begin{aligned}\text{Raw TWD} = {} & b_0 + b_1 \text{ (Car 2)} + b_2 \text{ (Car 3)} \\ & + b_3 \text{ (Car 4)} + b_4 \text{ (Car 5)} \\ & + b_5 \text{ (Car 6)} + b_6 \text{ (Car 7)} \\ & + b_7 \text{ (Car 8)} + b_8 \text{ (Rater B)} \\ & + b_9 \text{ (Day 2)} + b_{10} \text{ (Day 3)} \\ & + b_{11} \text{ (Day 4)} + b_{12} \text{ (Day 5)} \\ & + b_{13} \text{ (Day 6)} + b_{14} \text{ (Day 7)} \\ & + b_{15} \text{ (Day 8)} + b_{16} \text{ (Day 9)} \\ & + b_{17} \text{ (Day 10)} + b_{18} \text{ (Day 11)}\end{aligned} \qquad (1)$$

Base Case is Car 1, Rater A, Day 1

*(Car "n"), (Rater "m"), and (Day "n") are dummy variables whose value is 1.0 for observations with car "n", Rater "m", and day "n", and whose value is 0.0 otherwise. For example, for car 2 (Rater B) on day 2, the equation becomes: TWD = $b_0 + b_1 + b_8 + b_9$.

DATA	EQUATION FORM	EQUATION NUMBER

LOW TEMPERATURE PHASE (Continued)

Days 1-11 (Continued)

Cars 9-16

$$\text{Raw TWD} = b_0 + b_1 \text{ (Car 10)} + \ldots b_7 \text{ (Car 16)} + b_8 \text{ (Rater B)} + b_9 \text{ (Day 2)} + \ldots b_{18} \text{ (Day 11)} \ldots \quad (2)$$

Base Case is Car 9, Rater A, Day 1

Days 15-26

Cars 1-8

$$\text{Raw TWD} = b_0 + b_1 \text{ (Car 2)} + \ldots b_7 \text{ (Car 8)} + b_8 \text{ (Rater C)} + b_9 \text{ (Day 16)} + \ldots b_{19} \text{ (Day 26)} \quad (3)$$

Base Case is Car 1, Rater D, Day 15

Cars 9-16

$$\text{Raw TWD} = b_0 + b_1 \text{ (Car 10)} + \ldots b_7 \text{ (Car 16)} + b_8 \text{ (Rater C)} + b_9 \text{ (Day 16)} + \ldots b_{19} \text{ (Day 26)} \quad (4)$$

Base Case is Car 9, Rater D, Day 15

DATA	EQUATION FORM	EQUATION NUMBER

INTERMEDIATE TEMPERATURE PHASE

Days 1-14

Cars 1-8	Raw TWD = $b_0 + b_1$ (Car 2) $+ \ldots b_7$ (Car 8) $+ b_8$ (Rater E) $+ b_9$ (Rater G) $+ b_{10}$ (Day 2) $+ \ldots b_{22}$ (Day 14)	(5)
	Base Case is Car 1, Rater D, Day 1	
Cars 9-16	Raw TWD = $b_0 + b_1$ (Car 10) $+ \ldots b_7$ (Car 16) $+ b_8$ (Rater E) $+ b_9$ (Rater G) $+ b_{10}$ (Day 2) $+ \ldots b_{22}$ (Day 14)	(6)
	Base Case is Car 9, Rater D, Day 1	

Days 15-26

Cars 1-8	Raw TWD = $b_0 + b_1$ (Car 2) $+ \ldots b_7$ (Car 8) $+ b_8$ (Rater I) $+ b_9$ (Day 16) $+ \ldots b_{19}$ (Day 26)	(7)
	Base Case is Car 1, Rater H, Day 15	

DATA	EQUATION FORM	EQUATION NUMBER

INTERMEDIATE TEMPERATURE PHASE (Continued)

Days 15-26 (Continued)

Cars 9-16	Raw TWD = $b_0 + b_1$ (Car 10) $+ \ldots b_7$ (Car 16) $+ b_8$ (Rater I) $+ b_9$ (Day 16) $+ \ldots b_{19}$ (Day 26)	(8)

Base Case is Car 9, Rater H, Day 15

After a few iterations, it was discovered that three observations were outliers. They were observations 255, 878, and 901. Detailed results of these regressions after eliminating the outliers are shown in Table D-1. Pertinent results for rater corrections are:

Base Rater	Variable	Coeff.*	s.e. of Coeff.	t-Value**	Coeff.*	s.e. of Coeff.	t-Value**
		Equation 1			Equation 2		
Rater A	b_8 (Rater B)	41.7	25.3	1.6	21.7	30.6	0.7
		Equation 3			Equation 4		
Rater D	b_8 (Rater C)	33.7	8.4	4.0	14.9	16.9	0.9
		Equation 5			Equation 6		
Rater D	b_8 (Rater E)	11.1	16.0	0.7	27.8	17.5	1.6
Rater D	b_8 (Rater G)	-15.0	12.6	1.2	-21.1	15.2	1.4
		Equation 7			Equation 8		
Rater H	b_8 (Rater I)	35.3	12.3	2.9	36.1	15.8	2.3

*Coefficient is the Δ TWD between Base Rater and Rater shown in the "Variable" column.

**Must be $\geq$ 2.0 to assure coefficient is not zero at the 95% confidence level.

From Equations 1 and 2:

Average Rater A TWD - Average Rater B TWD[1] = -32.7

Standard error of Δ TWD[2] = 19.2

t-Value = 1.7

From Equations 3 and 4:

Average Rater D TWD - Average Rater C TWD[1] = -30.0

Standard error of Δ TWD[2] = 7.5

t-Value = 4.0

From Equations 5 and 6:

Average Rater D TWD - Average Rater E TWD[1] = -18.7

Standard error of Δ TWD[2] = 11.8

t-Value = 1.6

Average Rater D TWD - Average Rater G TWD[1] = 17.5

Standard error of Δ TWD[2] = 9.7

t-Value = 1.8

From Equations 7 and 8:

Average Rater H TWD - Average Rater I TWD[1] = -35.6

Standard error of Δ TWD[2] = 9.7

t-Value = 3.7

(1) Wt. Average Δ TWD

$$= \frac{\dfrac{\Delta\ \text{TWD}_1}{(\text{s.e.}_1)^2} + \dfrac{\Delta\ \text{TWD}_2}{(\text{s.e.}_2)^2}}{\dfrac{1}{(\text{s.e.}_1)^2} + \dfrac{1}{(\text{s.e.}_2)^2}}$$

(2) Standard error of wt. average TWD $= \left[\sqrt{\left(\frac{1}{\text{s.e.}_1}\right)^2 + \left(\frac{1}{\text{s.e.}_2}\right)^2}\right]^{-1}$

STEP 2: Determine offsets between raters not on-site simultaneously.

The second step in the rater correction process was to determine differences between raters on-site during the first and last half of each program phase. Recall that in regressions 1-8, offsets from a base case were calculated for each car, rater, and day. The day offsets are actually the day-to-day (or fuel-to-fuel) differences by the base rater averaged across all cars without variability due to cars or raters. To compare base raters (i.e., A and D in the low temperature phase, and D and H in the intermediate temperature phase), results of regressions 1-8 were used as shown in Table D-2 to calculate daily TWD. At this point, an investigation was included to determine whether ambient temperature was a significant variable within the program phases. The data for each phase were divided into two segments based again on test cars. One grouping was cars 1-8 and another grouping was cars 9-16. In the low temperature phase, data for test days 12, 13, and 14 were again eliminated. The four applicable equations are:

DATA	EQUATION FORM	EQUATION NUMBER
LOW TEMPERATURE PHASE		
Cars 1-8	Day Offset TWD = $b_0 + b_1$ (Rater D) + b_2 (Soak Temperature) + b_3 (Fuel 1) + b_4 (Fuel 3) + ... b_{10} (Fuel 9)	(9)
	Base Case is Rater A and Fuel 2	
Cars 9-16	Day Offset TWD = $b_0 + b_1$ (Rater D) + b_2 (Soak Temperature) + b_3 (Fuel 1) + b_4 (Fuel 3) + ... b_{10} (Fuel 9)	(10)
	Base Case is Rater A and Fuel 2	